# PRACTICAL AGRICULTURAL ENGINEERING

R K GHOSH  S SWAIN

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**R K GHOSH**

**&**

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*To*

*The memory of*

*Late Krishna Chandra Ghosh (father of R K Ghosh)*

&

*Late Yudhisthir Swain (father of S Swain)*

# PREFACE

The branch of agricultural engineering was not widely known in India the before sixties. With the inception of agricultural universities the situation started changing. At present it has established its roots in the Indian soil. But it is young in comparison with civil, electrical or mechanical engineering. Hence, the practical lessons are yet to be arranged in a systematic manner in Indian laboratories/workshops. As such no practical books are available in the Indian markets. Accordingly, a primary attempt has been made towards this direction.

The book is designed primarily as an elementary practical text book for students of agricultural engineering degree programme or/and agriculture degree programme. It may also serve as an help study for students at the post-graduate level in agricultural engineering or agricultural colleges/universities. In addition to the student readership, the book will be a valuable reference to professional engineers and agricultural scientists working in the field. The students/trainees in agricultural polytechnics, krishi vigyan kendras, rural institutes and similar other organisations having a programme in agriculture or agricultural engineering would find this book useful. It is also hoped that the book will be valuable to similar groups in the developing countries of Asia and Africa.

The book is organised in sixteen chapters. The first chapter deals with the general instructions. Chapterss II to VII deal with the soil and water engineering, Chapter VIII to XV deal with the farm machinery and power discipline.

The authors are deeply conscious of their serious limitations in writing a book of this nature which is first of its kind. It is likely that the technique of presentation may raise controversy. The authors will deeply appreciate constructive criticism and suggestions from teachers, students and professional engineers /scientists which will help to improve further the subject matter.

**Ranjit Kumar Ghosh**

December, 1989 **Satyananda Swain**

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# 1

# Introduction

## 1.1 GENERAL INSTRUCTIONS

The experiment or study proposed to be carried out should be understood thoroughly and all successive steps to be followed be kept in mind. The personal materials (e.g., pencil, eraser, divider, protector, pen, etc.) required for this purpose should be readily available with the worker.

### 1.1.1 CONDUCTING EXPERIMENT

( i ) A list of all apparatus, materials and accessories required for this should be prepared and compared while arranging for the experiment.

(ii) All steps should be very methodical and neat.

(iii) The data collected should be recorded appropriately and honestly. The date, time, place of the record should also be noted therein.

(iv) Recording of data in a tabular form is always good. Suitable headings of each column or row with appropriate units are also required for each table. It must be prepared in such a manner that another person may understand or visualise whole thing just by a glance.

(v) If there is any mistake in recording or if any data is required to be rejected, it should be penned through keeping it legible in future.

(vi) Repetitions of the experiment under unattended conditions as well as under attended conditions are essential to reduce or eliminate random and systematic errors.

(vii) The variable having the highest exponent (i.e., power) should be measured with highest precision than the rest.

(viii) The experiment should be conducted in such a manner that the relative error due to each variable remains more or less equal.

(ix) Precision of calculation of the final result and precision of measurement should be consistent.

( x) All precautions should be taken and written explicitly at the right place.

(xi) After finishing the work, the apparatus and accessories should be dismantled and cleaned carefully and returned to the store or to its appropriate place.

## 1.2 HOW TO REPORT THE EXPERIMENTAL WORK

*Title* : Title of the experiment should be written clearly.

*Theory* : A brief discussion of the theoretical background of the proposed experiment containing all formulae (without any deduction) with significance of the symbols used therein along with their units should be written. Any specific aims and objectives which are not clear from the title may also be written here.

Sometimes a machine or equipment becomes the object of an experiment. The identification of different parts, knowledge on the combination of parts to form units and sequential arrangement of the units to meet the functional requirements of the machine forms the basis for the experiment. In such cases, a brief outline about the importance of the machine may replace the theoretical background.

*Apparatus or Materials and Methods or Experimental Accessories* :

There is no need to describe the apparatus or its mode of action. But a complete list of all such of apparatus should be given.

*Diagram* : Plan, elevation, side view or line diagram of a machine or implement with its labelled parts are essential. In case of an assembled experimental set-up, the line diagram of the set-up (e.g., Fig. 4.24) with properly labelled units is to be given. If the machine under study or the apparatus used in the experimental set-up is complicated, a photographic or pictorial view may be presented (e.g., Fig. 3.1)

*Procedure* : After completion of the work, what has been done from the beginning to the end (including a short outline on how the data are processed) is to be written briefly. If the record of the data is very clearly shown, then a brief procedure is sufficient. The past passive tense (viz., the experiment was conducted in between 0700 hours to 1700 hours for every consecutive 30-day time period) in the write up of a procedure is an accepted practice. (Following this the procedure is written in this book in such a fashion that an worker is reporting his work to others. So it is not prepared in direct voice like other books. It is similar to that of a student's laboratory notebook or copy.)

*Experimental data* : Procedure explained in (iii) to (v) in Article 1.1.1 may be followed herein.

*Calculation and Results* : How the data are being processed should be shown for one or two samples and for the rests the results may be tabulated, if the data are large. Otherwise, all calculations in details which made to arrive at the final result must be shown. Log tables or calculators may be used for calculations. Knowledge of calculations using log tables is essential even if one uses a calculator. This will help to check, if one has pushed the wrong key of the calculator or if the calculator shows wrong results because of one reason or the other.

Units in the ultimate result should be clearly written. To establish functional relations between the measured variables, the data may be plotted on graph papers. This is separately explained in articles 1.4, 1.5 and 1.6.

*Precautions* : Really important precautions should be written, if not written at the appropriate places in the record of data. While studying an implement/equipment, the indirect observations/calculations/valuable information which would not be put directly under the observation may be put under the heading Remarks instead of Precautions. The utility of the machine can also be put under this heading.

## 1.3 GRAPHS

In order to understand the trend of two parametric relations obtained through experimental observations, graphical representation is usually made. For experiments involved with three variables, a three-dimensional plot may help to understand the trend but three-dimensional graph papers in a two-dimensional paper is not available in the market. The complexities of a problem increase with the increase in the number of parameters more than three. Hence, the usual practice to tackle a set of data of an experiment containing three or more parameters is to group the data and express those in some manageable ratios so as to get ultimately two such ratios. This helps us to plot these ratios just like a two-parameter data sets to understand the trend or their interrelationship.

Suppose $v_i$ and $v_d$ denote independent and dependent variables, respectively. This means that the value of $v_d$ depends on $v_i$. So, $v_i$ may be allowed to change at will generally in convenient equal gaps/steps and the corresponding value of $v_d$ may be observed through experiment. The data of $v_i$ versus $v_d$ are then plotted on a squared graph paper (commonly known as plain graph paper). The following steps may be followed for plotting :

(a) The variable $v_i$ shall be plotted along the horizontal axis or abscissa or colloquial $x$-axis and the $v_d$ along the vertical axis or ordinate or colloquial $y$-axis. By the side of the axis the variable so plotted should be clearly and briefly written with its units which should be chosen in a comparable simple ratio of the available length of the graph paper in such a fashion that the available size of the graph paper is more or less covered by the plot.

(b) The quantitative value of the $v_i$ and $v_d$ should be written on the squared paper.

(c) The data or the experimental values are then plotted by a small dot and enclosed by a small circle.

(d) The data points thus plotted may not always appear to lie on a straight line or smooth curve. The usual practice is to draw a straight line or a smooth free-hand curve so that the sum of the vertical distances of the points lying below the proposed straight line or curve is equal to that above it. If any point is found to lie far off the proposed line or curve that may be rejected, the small circle drawn surrounding a plotted point shall not be cut but left as such while drawing a straight line or curve lying exactly on it. It may very often be found that no data point lies on the proposed line or curve drawn for this purpose. By the term smooth free-hand curve is meant that there should be no sudden change of curvature in the graph. If needed, a legend to explain what is what shall be provided.

By practice, the skill in drawing good graphs can be achieved. For drawing of curves, "French curves" can suitably be used. In order to self-help in realising the precision of the measurements, it is always better to draw graphs from own experimental observations whatever possible.

## 1.4 HOW TO DRAW A BEST FIT STRAIGHT LINE

The least squares method prescribed in statistics may be followed. Let $v_d = mv_i + c$ be the proposed equation in which $m$ and $c$ are constans to be determined from a set of $n$ observations. Then

$$m = \frac{n\,\Sigma v_i v_d - \Sigma v_i \Sigma v_d}{n\,\Sigma v_i^2 - (\Sigma v_i)^2} = \frac{n\,\Sigma v_i v_d - \Sigma v_i \Sigma v_d}{p} \tag{1.1}$$

$$c = (\Sigma v_i^2 \Sigma v_d - \Sigma v_i \Sigma v_i v_d)/p \tag{1.2}$$

$$\text{so, in } v_d = mv_i + c \tag{1.3}$$

$m$ and $c$ are numerical figures/values with positive or negative sign(s) obtained by least squares method. Now three $v_i$-values may be assumed suitably with equal gaps in between two consecutives and reasonably far apart. Putting these $v_i$'s in Eq (1.3), $v_d$-values may be generated. These three generated data points may then be plotted with small dots only in the same graph where observed data on $v_i$ versus $v_d$ have been plotted and encircled using the same scale and units of the plot. These three dots will now be joined by a straight line. Whether the sum of the vertical distances of the encircled points (with reference to this drawn line) lying above and below this line is more or less equal or not must be inspected.

## 1.5 HOW TO DRAW A BEST FIT CURVE OTHER THAN A STRAIGHT LINE

A straight line can be drawn with a better skill and efficiency in comparison to the curves. In this process, it is, therefore, always tried to fit the data set in such a manner that ultimately a dependent variable ($y$) can be expressed linearly with the independent variable ($x$) in a plot on plain graph or semi-log or log-log graph papers. But there exist some regular curves, (such as in Figs. 1.1 to 1.4, 1.20, 1.21, etc.) which may not successfully be transformed into straight lines in any plot. Hints on the nature of equations depending on the nature of plots/curves are given in Figs. 1.1 through 1.22. The data of Fig. 1.7 may yield straight line if $\frac{x}{y}$ versus $x$ are plotted in plain graph. The data of Fig 1.8 may be straight line if $\frac{1}{y}$ versus $\frac{a_0 + a_1 x}{a_2 + x}$ are plotted in plain graph. In semi-log graph, the data of Figs. 1.9, to 1.13, may yield straight line. The data of Figs 1.5, 1.6, 1.15 to 1.19 if plotted in log-log graph papers, will produce straight lines. Similarly, data of other graphs except those in Figs. 1.1 to 1.4, 1.7, 1.8, 1.20–1.22 may suitably be plotted in semi-log or log-log to obtain straight lines. If the plot is a straight line in semi-log or log-log, the equations are of the following forms as :

$$\log\ y = \log a_0 + a_1 x \tag{1.4}$$

$$\text{or } y' = a_0' + a_1 x \tag{1.5}$$

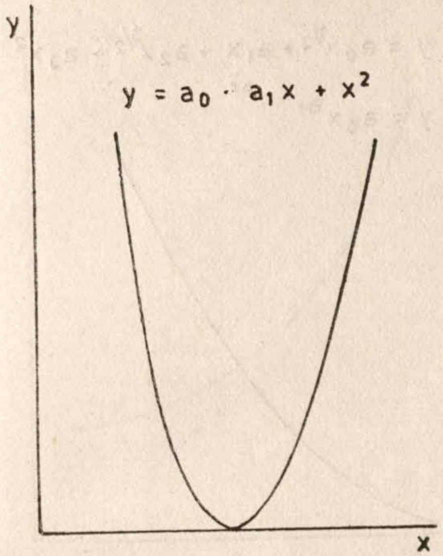

Fig. 1.1

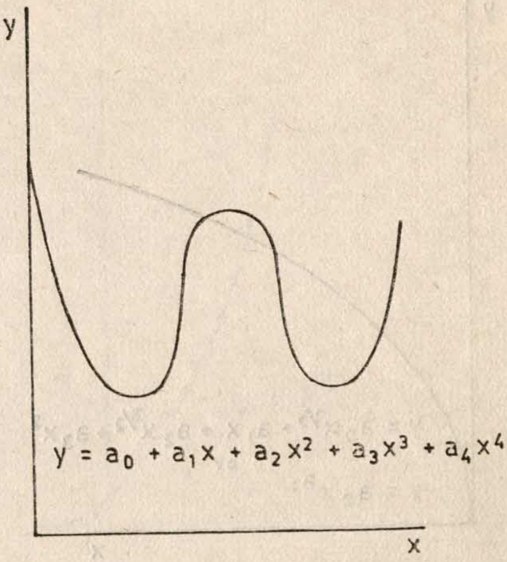

Fig. 1.2

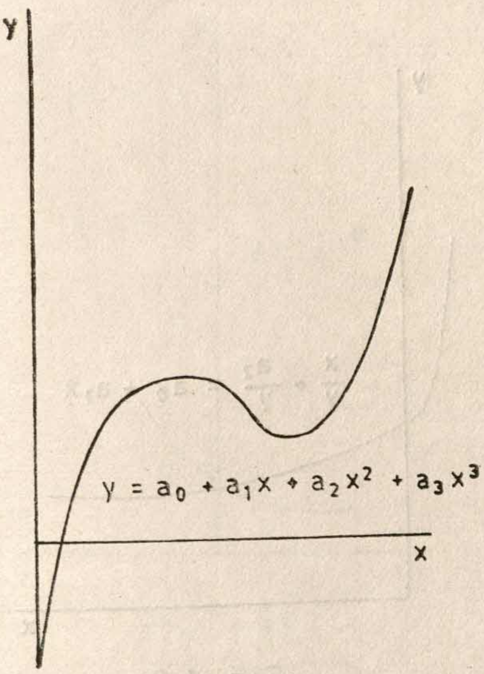

Fig. 1.3

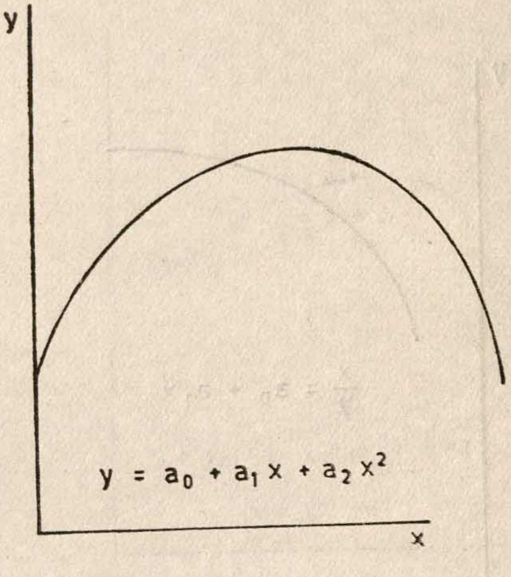

Fig. 1.4

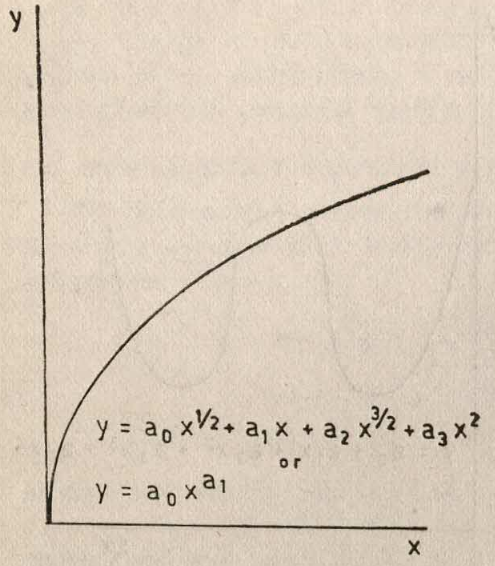

Fig. 1.5

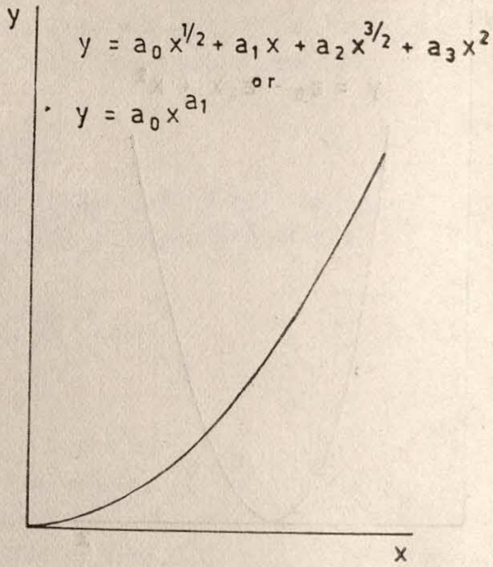

Fig. 1.6

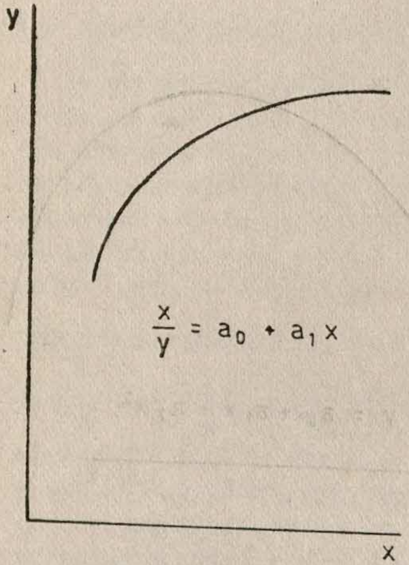

Fig. 1.7

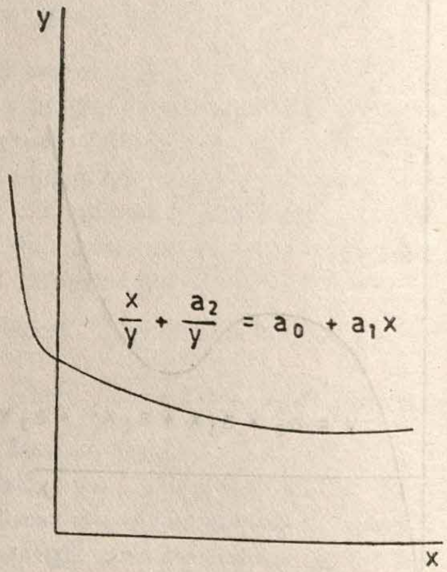

Fig. 1.8

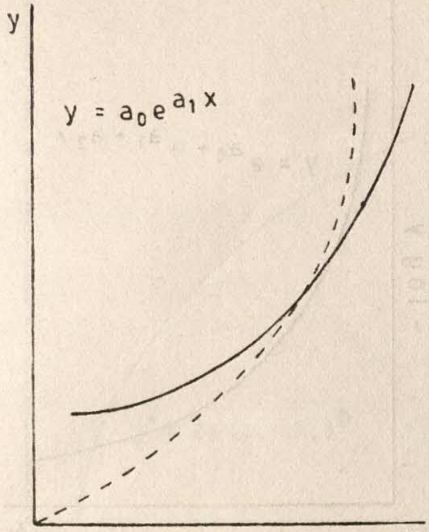

Fig. 1.9

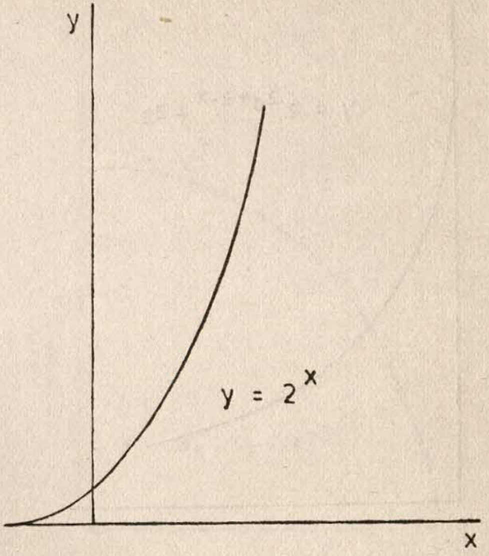

Fig. 1.10

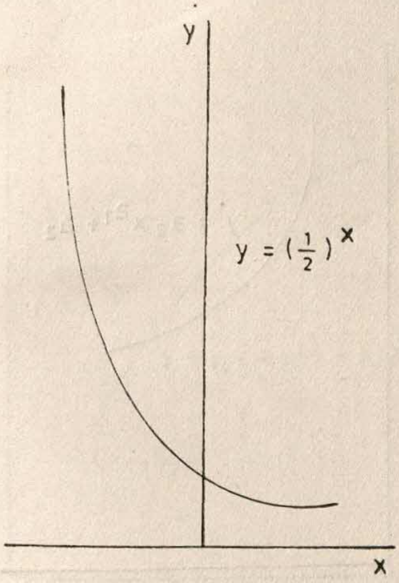

Fig. 1.11

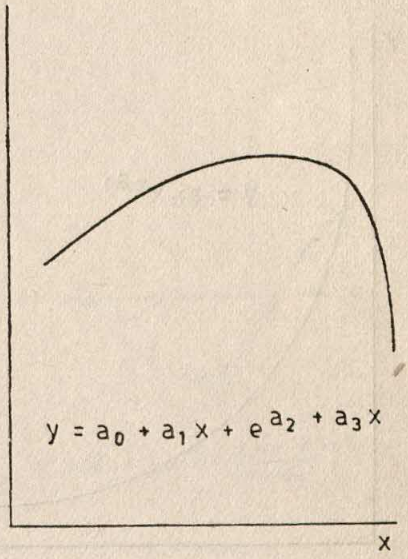

Fig. 1.12

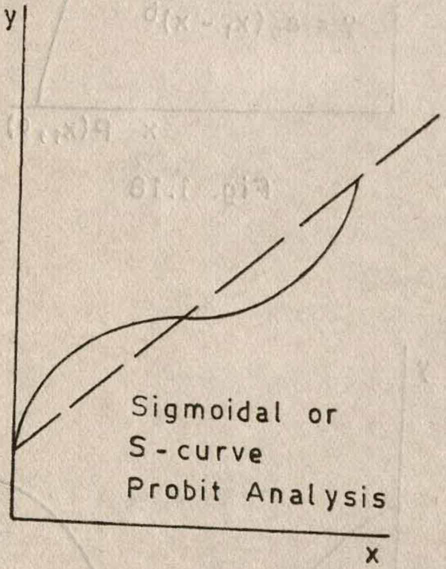

Fig. 1.21

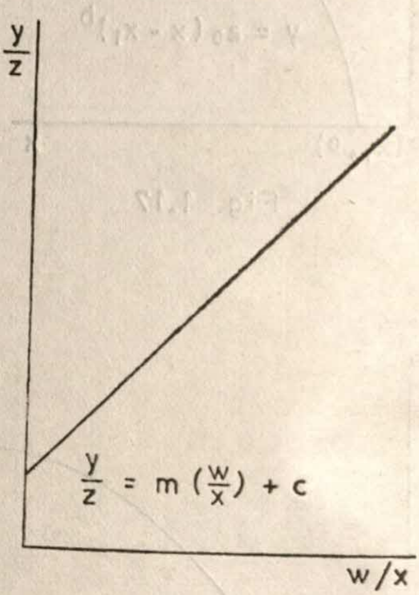

Fig. 1.22

Or

$$\log\ y=\log a_0+a_1 \log x \tag{1.6}$$

$$\text{i.e.,}\ \ y'=a_0'+a_1x' \tag{1.7}$$

The equations (1.5) and (1.7) are very similar to that of Eq (1.3) and hence, following the same procedure of least squares method, the best values of $a_0'$, $a_1$ can easily be obtained.

To obtain the best values of constants using least squares method for polynomials of 3rd, 4th or *n*th power of *x*, any standard book on statistics may be consulted.

With a little practice, the regular trigonometric curves like that shown in Fig. 1.20 may be fitted suitably. It needs a separate treatment for *S*-curves as shown in Fig. 1.21. This is a case of probit analysis (statistics).

Sometimes, the number of variables in one experiment may be more than two. Under such circumstances, the grouping of variables following dimensional analysis or any empirical or other methods is required to facilitate the plot in two-dimensional space as shown in Fig. 1.22.

## 1.6 ERRORS

Any type of measurement involves errors, e.g., gross, systematic and random errors. Systematic error may be environmental or external, observational or personal and instrumental error(s). Even, if the instrument is good and reasonable care is taken to handle this, there exist errors due to parallax or due to personal judgement of the observer. Thus, no physical measurement is ever exact. For precautionary measures to avoid errors, any standard book on elementary practical physics may be looked into. In case of unavoidable circumstances, the error may remain and hence, statistical methods may be followed to estimate the standard deviation, quantum of error or the chance of getting actual value, etc. Reference may be made to any standard book on statistics for such treatments.

# 2

# Rainfall Analysis

## 2.1 ANALYSIS OF POINT RAINFALL AND ITS INTENSITY

*Theory* : A non-recording rain gauge measures only the total depth of rain that has fallen on the surface of the earth in a certain period of time whereas a recording rain gauge measures both the depth as well as its variations with respect to time. A rain guage represents the rainfall of wide area, though it records rainfall only at a point. The analysis of rainfall data obtained through a single rain gauge is, therefore, commonly denoted as point rainfall analysis.

A graphical or pictorial display of a rainfall event is automatically obtained from a chart of any recording rain gauge. The trace obtained in a rainfall chart is a curve of cumulative rainfall versus time but splitted up into several parts depending on the length of the vertical axis (in other words, the capacity of the rain collecting can) and the amonnt of rainfall. The intensity of rainfall is, therefore, obtained from the trace by noting the amount of rain which has fallen in a short time centred around a chosen point. In other words, the slope of the tangent at any chosen point on the trace reveals the rainfall intensity for that instant.

Let the line $AB$ (drawn arbitrarily) in Fig. 2.3 represents a rainfall event. The slope of $AB$, i.e., $CB/AC$, i.e., 10/5 or 2 mm/hr is the rainfall intensity (uniform).

Let $P$ be a point on the trace at any time, $t$. Assume two other points (on the trace) $P_1$ and $P_2$ on both sides of $P$ such that $P_1 \rightarrow P_2$. Corresponding to $P_1$ and $P_2$ let $t_1$ and $t_2$ be the time. The intensity at $P$ may then be determined as $P_1P_2/(t_1 \sim t_2)$.

*Materials* : A rain gauge chart from a float-and-syphon type rain gauge (Figs. 2.1 and 2.2).

*Procedure* : The rain gauge chart (Fig. 2.3) representing rainfall for 24 hr was collected from a float-and-syphon type rain gauge. It was analysed in the line of theory.

*Analysis* : The chart is numbered as 395 (S 5417) and has a range of 10 mm of rainfall. The float chamber has a capacity of 323·5 cm$^3$ with a funnel of 203 mm in diameter. This is equivalent to 10 mm of rain (vertical depth). When this can is full, the syphoning starts. The vertical lines (trace) in Fig. 2.3 indicate the syphoning actions (completed within 15 to 20 sec in which period rainfall could not be recorded). To analyse this event some points are chosen on the trace wherever the intensity changes. In Fig. 2.3 the event within 1600 to 2100 hr is spotted at ten points and its analysis is shown in Table 2.1. This analysis is up to 20 hr 40 min time period. The same procedure be followed afterwards.

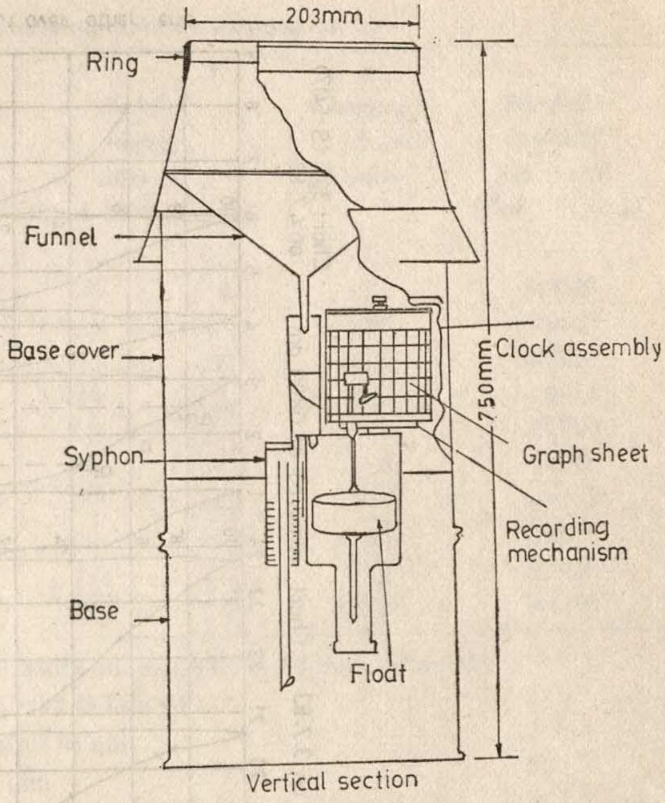

Fig. 2.1 A line sketch of an automatic recording type (float-and-syphon) rain gauge.

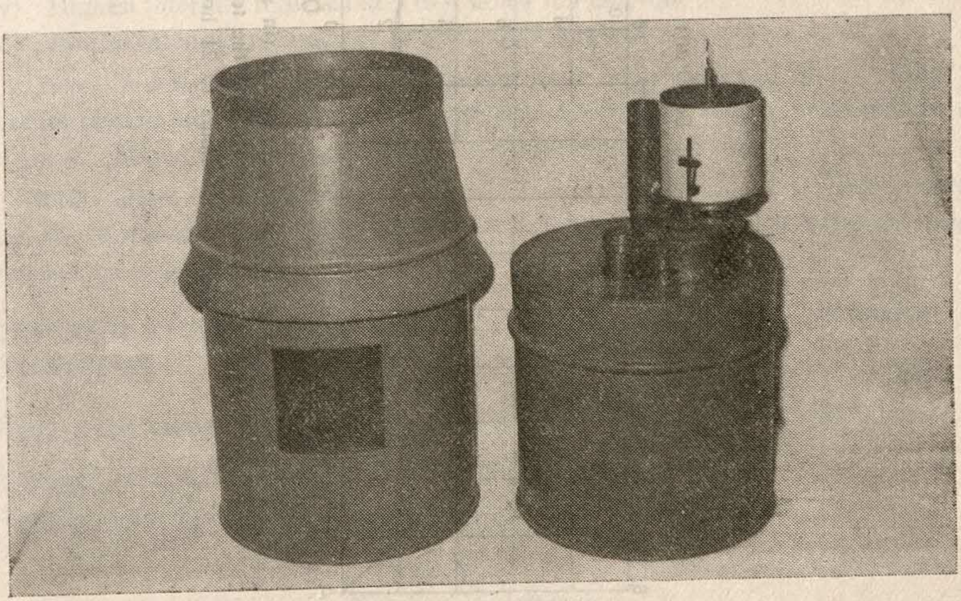

Fig. 2.2 Photographic view of a recording type rain gauge.

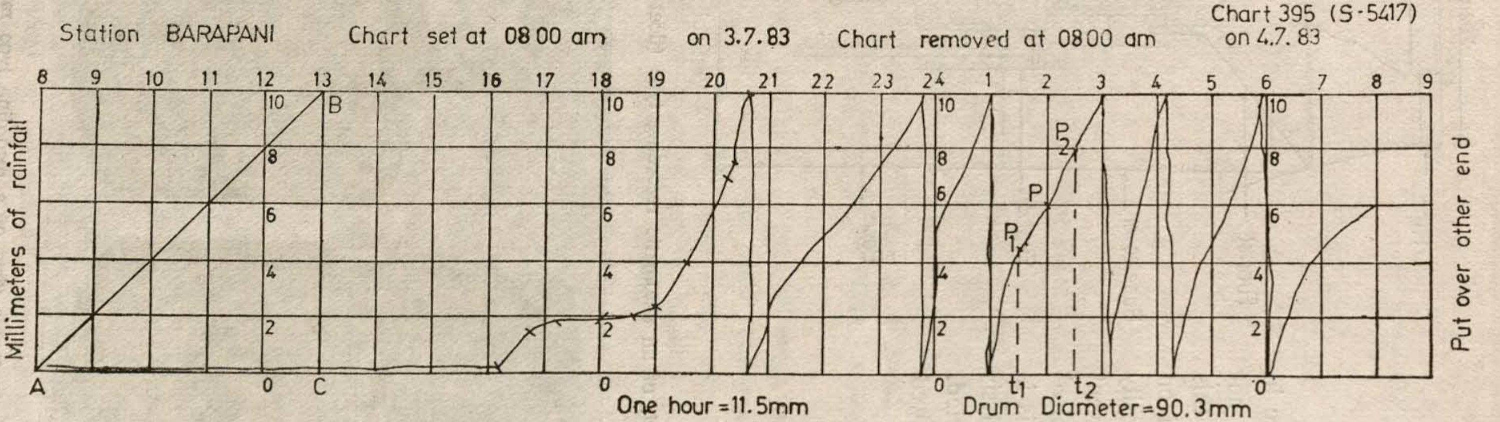

Fig. 2.3 Rain-gauge chart (in a reduced scale) of a float-and-syphon type rain gauge. The line *AB* and the ten spotted marks on the rainfall curve in between 16 hours to 21 hours are drawn by hand for the purposes of illustration and analysis.

Table 2.1 Analysis of rain-gauge chart shown in Fig. 2.3

| 1 *Clock time* | 2 *Time interval* (min) | 3 *Cumulative time* (min) | 4 *Rainfall during interval* | 5 | 6 *Cumulative rainfall* (mm) | 7 *Rainfall÷ intensity* (mm/min) (Col 5÷Col 2) |
|---|---|---|---|---|---|---|
| | | | *Chart Div** | (mm) | | |
| 16·10 | — | — | — | — | — | — |
| 16·45 | 35 | 35 | 3·0 | 1·5 | 1·5 | 0·0429 |
| 17·00 | 15 | 50 | 0·3 | 0·15 | 1·65 | 0·0100 |
| 17·15 | 15 | 65 | 0·1 | 0·05 | 1·70 | 0·0033 |
| 18·00 | 45 | 110 | 0·2 | 0·10 | 1·80 | 0·0022 |
| 18·35 | 35 | 145 | 0·3 | 0·15 | 1·95 | 0·0043 |
| 19·00 | 25 | 170 | 0·8 | 0·40 | 2·35 | 0·0160 |
| 19·30 | 30 | 200 | 3·2 | 1·60 | 3·95 | 0·0533 |
| 20·15 | 45 | 245 | 6·1 | 3·05 | 7·00 | 0·0678 |
| 20·20 | 5 | 250 | 1·0 | 0·50 | 7·50 | 0·1000 |
| 20·40 | 20 | 270 | 5·0 | 2·50 | 10·00 | 0·1250 |

*0–2 vertical scale is divided into 4 equal parts and one part is 0·5 mm of rainfall.

The general observations on Fig. 2.3 are as follows :

(i) Total duration of rainfall=16 hr 50 min
(ii) Total amount of rainfall=66 mm
(iii) Average intensity=0·0653 mm/min
(iv) Highest intensity recorded at 3 to 4 hr=0·133 mm/min
(v) Lowest intensity recorded at 18 hr=0·0022 mm/min

*Salient precautionary points* : Rain gauges are of many types and makes. Exact procedure for rainfall analysis may differ (though general principles remain unaltered) depending on these. Manufacturers' manuals may be consulted for each case.

Rain gauges are installed on a good platform placed over the ground surface such that the distance from any obstruction to the gauge is at least twice the height of obstructions from all sides.

## 2.2 DETERMINATION OF RAINFALL CHARACTERISTICS (INTENSE AND EXCESSIVE)

*Theory* : The rainfall is considered as intense if $P \geqslant \left(0{\cdot}2+\frac{t}{100}\right)$ inch where $P$ is the actual rainfall in inch and $t$ is the actual duration in minute.

Similarly, rainfall is considered excessive when

$$I \geqslant \frac{0{\cdot}2+\frac{t}{100}}{t} \times 60 \text{ inch}$$

where $I$ is the actual maximum intensity of rainfall in iph and $t$ as above.

*Materials required* : Rainfall data of a place.

*Procedure* : Rainfall and some relevant meteorological data (other than the present needs) of a place were collected from a station and shown in Table 2.2

*Observations* :

Table 2.2 Meteorological data recorded in a station (72·7°E, 22·7°N) and averaged monthwise for the period of 22 years

| *Month* | *Rainfall* (mm) | *Number of rainy days* | *Temperature* (°C) *Maximum* | *Minimum* | *Average sunshine hour per day* |
|---|---|---|---|---|---|
| Jan | 0·5 | 0 | 26·1 | 11·0 | 9·5 |
| Feb | 0·4 | 0 | 29·0 | 13·1 | 10·1 |
| March | 1·1 | 0·1 | 33·0 | 17·0 | 10·0 |
| April | 2·2 | 0 | 36·3 | 21·1 | 10·4 |
| May | 3·2 | 0·2 | 36·0 | 24·5 | 10·9 |
| June | 129·4 | 5·1 | 33·0 | 24·4 | 8·2 |
| July | 264·9 | 12·0 | 29·1 | 23·5 | 4·3 |
| Aug | 264·9 | 11·3 | 27·8 | 22·7 | 3·7 |
| Sept | 162·3 | 7·0 | 29·0 | 21·3 | 6·9 |
| Oct | 10·3 | 0·9 | 32·2 | 19·0 | 9·6 |
| Nov | 15·1 | 0·9 | 30·1 | 15·9 | 9·3 |
| Dec | 3·2 | 0·2 | 27·1 | 13·3 | 9·1 |

*Calculations* : For January $P=\frac{0\cdot5}{10\times2\cdot54}=0\cdot02''$ (approx.)

and $t=0$ ; thus $0\cdot2+\frac{t}{100}=0\cdot2''$

$$\therefore\quad P \ngeq \left(0\cdot2+\frac{t}{100}\right)$$

Hence, the rainfall in January is not intense.

$$\text{Again}\quad \frac{0\cdot2+\frac{t}{100}}{t}\times60=\frac{0\cdot2\times60}{0}=\text{undefined}$$

$$\text{Thus}\quad I \ngeq \frac{0\cdot2+\frac{t}{100}}{t}\times60$$

The rainfall in January is, therefore, not excessive.

Similar interrelations are determined for February to December.

*Conclusions* : The rainfall was neither intense nor excessive for all the months.

## 2.3 DETERMINATION OF THE CLIMATIC CHARACTER OF A REGION

*Theory* : Precipitation Effectiveness (PE) index is a tool by which aridity or humidity of a region can be decided. According to Thornthwaite

$$\text{(PE) index} = 115\left(\frac{P}{T-10}\right)^{\frac{10}{9}} \tag{2.1}$$

where $P$ is the monthly rainfall or precipitation in inch and $T$ is the mean monthly temperature in °F.

Let $N$ be the number of years for which the (PE) indices are being considered to arrive at a conclusion.

$$\text{Average Annual (PE) index} = \frac{\sum_{1}^{N} \text{Annual (PE) index}}{N}$$

where Annual (PE) index $= \sum_{1}^{12}$ Monthly (PE) index.

Based on the numerical value of the average annual (PE) index, the climatic character of a region may be decided as

| *Average annual (PE) index* | *Climate character* |
|---|---|
| More than or equal to 128 | Superhumid |
| Lies within 64–128 | Humid |
| Lies within 32–64 | Subhumid |
| Lies within 16–32 | Semiarid |
| Less than 16 | Arid |

*Materials Required* : Rainfall and temperature data for more than 10 years.

*Procedure* : Rainfall and temperature data of a place for about 22 years were collected from a meteorological station (Table 2.2). These were processed suitably as per theory.

*Observations* : Same as Table 2.2 (§ 2.2)

*Calculations* : The relation between °C and °F is

$$\left.\begin{aligned} \frac{C}{5} &= \frac{F-32}{9} \\ (°F) &= \frac{9}{5}\,(°C)+32 \end{aligned}\right] \tag{2.2}$$

Accordingly, the mean monthly atmospheric temperatures are converted to °F and presented in Table 2.3

*For January* : Mean temperature $(°F) = \frac{9}{5}\left(\frac{26{\cdot}1+11{\cdot}0}{2}\right)+32 = 65{\cdot}39$ °F

$$P = \frac{0{\cdot}5}{10\times 2{\cdot}54}\ \text{inch} = 0{\cdot}02''$$

$$(\text{PE})\ \text{index}=115\left(\frac{0{\cdot}02}{65{\cdot}39-10}\right)^{\frac{10}{9}}=0{\cdot}016$$

Calculated values of (PE) index for all the twelve months are given in Table 2.3.

Table 2.3 Calculated values of (PE) index along with basic data

| *Month* | *Rainfall* | | *Mean temperature* | | *(PE) Index* |
|---|---|---|---|---|---|
| | mm | inch | °C | °F | |
| Jan. | 0·5 | 0·020 | 18·55 | 65·39 | 0·016 |
| Feb. | 0·4 | 0·015 | 21·05 | 69·89 | 0·012 |
| March | 1·1 | 0·040 | 25·00 | 77·00 | 0·033 |
| April | 2·2 | 0·090 | 28·70 | 83·66 | 0·064 |
| May | 3·2 | 0·130 | 30·25 | 86·45 | 0·093 |
| June | 129·4 | 5·090 | 28·70 | 83·66 | 5·910 |
| July | 264·9 | 10·430 | 26·30 | 79·34 | 14·013 |
| Aug. | 264·9 | 10·430 | 25·25 | 77·45 | 14·450 |
| Sept. | 162·3 | 6·390 | 25·15 | 77·27 | 8·408 |
| Oct. | 10·3 | 0·410 | 25·60 | 78·08 | 0·388 |
| Nov. | 15·1 | 0·590 | 23·00 | 73·40 | 0·641 |
| Dec. | 3·2 | 0·130 | 20·20 | 68·36 | 0·125 |
| | | | | | Σ44·153 |

*Results* : The average annual (PE) index of the place lies in between 32–64 and hence, it is a subhumid region.

## 2.4 AVERAGE DEPTH OF RAINFALL OVER AN AREA

A rain gauge gives the rainfall at a given point where it is installed. The analysis of such data is, therefore, described as "Point Rainfall Analysis". Actually, there exist large variations in all the characters of a rainfall within short distances in all categories of earth surface, while one "Point Rainfall" (rain gauge) data is taken as a representative of a wide area. It is, therefore, necessary to compute the average rainfall over a given area when data from several rain-gauge stations are available. Of the several methods for determining the average depth of rainfall over an area where more than one rain gauge is used, only three methods are given below :

(A) Arithmetic mean
(B) Thiessen polygon method
(C) Isohyetal method

In case all the rain-gauge stations represent equal areas or all the rain gauges record equal rainfall, then all the above mentioned three methods will give the same result. But in reality it is found very often that each rain gauge does not represent equal area or non-uniform rainfall data is usually available from various rain gauges.

With this, the problem of data processing becomes complex. It is also a known fact that in uneven distribution, weighted mean is always better than arithmetic mean. Hence, arithmetic mean, though simplest of all the methods, is not so accurate in comparison with other two methods. For a storm on a particular watershed recorded in several rain gauges, the choice of the method (viz., *A* or *B* or *C*) will depend on the character of the rainstorm, distribution of rain gauges, area of the watershed and the number of rain gauges. It is better to adopt either *B* or *C* which gives more or less same result and the method *A* may be used as a preliminary yard stick.

### 2.4.1 ARITHMETIC MEAN

*Theory* : Let $P_1, P_2, P_3, \cdots, P_n$ be the depths of rainfall recorded in $n$ stations scattered throughout the concerned area. The average rainfall ($P$) may then be

$$P=\frac{1}{n}(P_1+P_2+P_3+\cdots+P_n) \text{ cm or inch}$$

*Materials* : Rainfall depth data for all the rain gauges.

*Procedure* : Data of rainfall depths were simply added and divided by the number of stations.

*Calculations* : For the area and data as shown in Figs. 2.4 and 2.5

$$P=\frac{8{\cdot}9+11{\cdot}1+15{\cdot}0+16{\cdot}0+14{\cdot}3+13{\cdot}2+11{\cdot}3}{7}\text{ cm}=\frac{89{\cdot}8}{7}\text{cm}=12{\cdot}828\text{ cm}$$

### 2.4.2 THIESSEN POLYGON METHOD

*Theory* : For weighted mean average as mentioned above, a common method to determine weight factors is to divide the areas by Thiessen network and to decide the area of influence of each rain gauge which is assumed to be best represented by the rainfall recorded in the enclosed rain gauge.

Using a scale for the map, the area is first of all drawn over a graph sheet. The rain gauges are marked on the map following the same scale. All such points (rain-gauge stations) are joined by straight lines to form a number of triangles. Perpendicular bisectors are then constructed in each side of such triangles. With this, each station is now enclosed by a polygon (i.e., a closed plane figure, especially one with more than four sides and angles). In actual case, it may not essentially possess more than four sides. For example, one or more such perpendicular bisectors and the remaining non-linear boundary line of the area may also form this polygon. These are referred to as Thiessen polygons. A critical inspection will reveal that all points within one polygon will be closer to its rain gauge than to any of the others. The essential points of this theory are to consider the rain recorded in a rain gauge as representative rainfall for that area which is closest to it.

Difficulties may arise in choosing the best polygon for each rain gauge from amongst various alternative sets of polygons. For this, trial and error is required and in general shorter lines as the sides of a polygon should be preferred over longer ones.

Let $P_1, P_2, P_3, \cdots, P_n$ be the depths of rainfall recorded in $n$ rain gauges enclosed by polygons having areas $A_1, A_2, A_3, \cdots, A_n$ within the watershed. The average depth of rainfall ($P$) in the watershed of area $A$ may then be

$$P=\frac{A_1P_1+A_2P_2+A_3P_3+\cdots+A_nP_n}{A_1+A_2+A_3+\cdots+A_n}=\frac{\sum_1^n A_iP_i}{A} \tag{2.3}$$

*Materials* : Rain gauges placed in stations, survey equipments, graph sheets, etc.

*Procedure* : The watershed area was surveyed and its boundary line was drawn on a graph sheet choosing a scale as shown in Fig. 2.4. The rain-gauge stations were located in the same map.

During the period of rain, the rainfall in each station was recorded.

As described, perpendicular bisectors were constructed over each straight line joined by two stations. It was found that several alternative polygons have been formed. Following trial and error, the best polygon was chosen in such a manner that all points within one polygon were closer to its rain gauge than to any of the others. The dotted lines represent the lines formed by joining any two stations and solid lines represent the sides of the polygons. All other extra lines were rubbed off from the Fig. 2.4.

The numbers of small squares of the graph paper within each polygon were counted and then converted appropriately either to the actual area or to area on the graph scale. As a check, the total area of the watershed was determined by planimetering or by counting the small squares. It was found that the total area and the summation of areas of all polygons were same.

*Observations and Calculations* :

Table 2.4 Data with refercence to Fig. 2.4

| *1* Thiessen area (sq mile) | *2* Rainfall (cm) | *3* Product (sq mile-cm) ( col 1 × col 2 ) |
|---|---|---|
| 1·37 | 8·9 | 12·193 |
| 0·80 | 11·1 | 8·880 |
| 0·70 | 15·0 | 10·500 |
| 0·75 | 16·0 | 12·000 |
| 0·69 | 14·3 | 9·867 |
| 1·22 | 13·2 | 16·104 |
| 2·05 | 11·3 | 23·165 |
| Σ7·58 | | Σ92·709 |

Average rainfall $=\frac{\Sigma \text{Product}}{\Sigma \text{Area}}=\frac{92\cdot709}{7\cdot58}=12\cdot23$ cm.

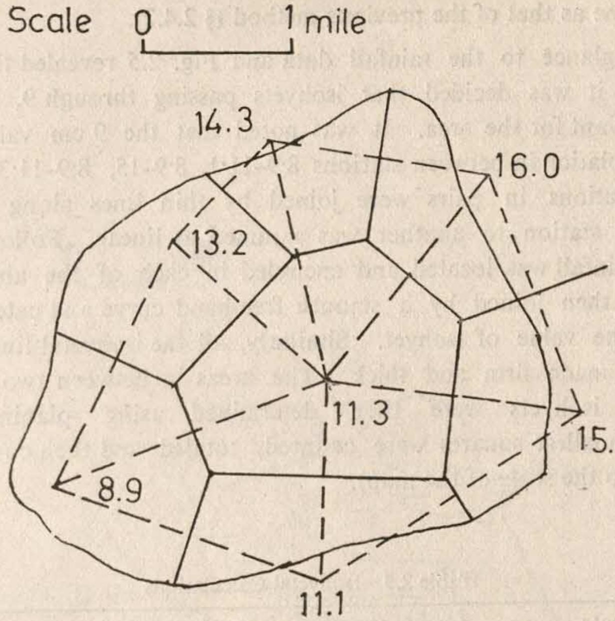

Fig. 2.4 Thiessen network. Solid lines are perpendicular bisectors of the dotted lines obtained by joining rain-gauge stations. Area of influence of each station is formed by polygon of solid lines enclosing the station.

### 2.4.3 ISOHYETAL METHOD

*Theory* : Sometimes, the rainfall is dominantly controlled by intense convection or by topography (e.g., rainfall usually increases with elevation) and hence, the Thiessen polygon theory fails. The present method may then be useful. Points of equal rainfall in an area if joined by a smooth free-hand curve, an isohyetal line is formed. This is very much akin in a sense to the contour lines on the ground surface. Hence, loosely the isohyets may be called as "rainfall contour". Isohyetal lines are drawn on a map by the method used in drawing contour maps (Article 7.1.3).

Let $P_0, P_1, P_2, P_3, \cdots, P_n, P_{n+1}$ be the values of the isohyetal lines ( in terms of depth of rainfall ) drawn on the map. The $P_0$ and $P_{n+1}$ isohyets may lie outside the watershed area or because of lack of data in outside area these may not actually be drawn. In effect, these two are assumed isohyets in proper sequence of the isohyet-interval. Let $A_1$ and $A_n$ be the areas enclosed by the boundary of the watershed and $P_1$ and $P_n$ isohyets, respectively ; $A_2, A_3, \cdots, A_{n-1}$ be the areas in between $P_1$ and $P_2$, $P_2$ and $P_3, \cdots, P_{n-1}$ and $P_n$ isohyets. The average rainfall ($P$) over the area may then be

$$P=\frac{\frac{P_0+P_1}{2}A_1+\frac{P_1+P_2}{2}A_2+\frac{P_2+P_3}{2}A_3+\cdots+\frac{P_n+P_{n+1}}{2}A_n}{A_1+A_2+A_3+\cdots+A_n} \tag{2.4}$$

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*Materials* : Same as that of the previous method (§ 2.4.2).

*Procedure* : A glance to the rainfall data and Fig. 2.5 revealed that the lowest rainfall was 8·9 cm. Thus, it was decided that isohyets passing through 9, 10, 11, 12, 13, 14 and 15 cm might be relevant for the area. It was noted that the 9 cm value of isohyet could be located by interpolation in between stations 8·9–11·1, 8·9–15, 8·9–11·3, 8·9–16·0, 8·9–14·3, 8·9–13·2. These stations in pairs were joined by thin lines along which the rainfall variation from one station to another was assumed as linear. Following unitary method, the 9-cm value of rainfall was located and encircled in each of the above-mentioned lines. These points were then joined by a smooth free-hand curve and extended slightly outside the area to write the value of isohyet. Similarly, all the isohyetal lines were drawn. The isohyets were then made firm and thick. The areas in between two isohyets or the areas enclosed by the isohyets were then determined using planimeter (in absence of a planimeter, the smallest squares were counted, totaled and then converted to the actual area with reference to the scale of the map).

*Calculations* :

Table 2.5 Isohyetal Calculations

| *Isohyets in Fig 2.5* | *Area between isohyets* (sq mile) *A* | *Average rainfall* (cm) *P* | *AP* (sq mile-cm) |
|---|---|---|---|
| 8–9 | 0·18 | 8·5 | 1·530 |
| 9–10 | 0·85 | 9·5 | 8·075 |
| 10–11 | 1·00 | 10·5 | 10·500 |
| 11–12 | 1·36 | 11·5 | 15·640 |
| 12–13 | 1·13 | 12·5 | 14·125 |
| 13–14 | 1·33 | 13·5 | 17·955 |
| 14–15 | 1·18 | 14·5 | 17·110 |
| 15–16 | 0·55 | 15·5 | 8·525 |
| | $\Sigma$ 7·58 | | $\Sigma$ 93·46 |

Average rainfall $=\frac{\Sigma AP}{\Sigma A}=12{\cdot}33$ cm.

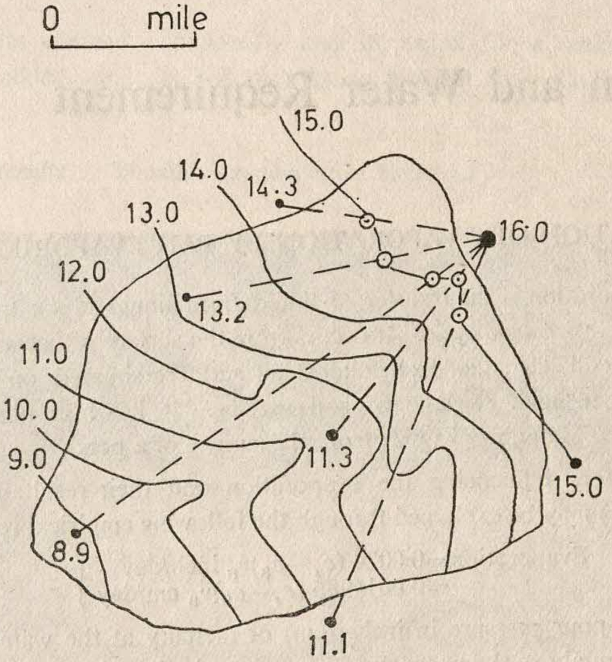


Fig. 2.5 Isohyetal map of the same area shown in Fig. 2.4. How the isohyetal line of 15-cm rain is obtained is demonstrated here using dotted lines and open circles. Other isohyets are obtained following the same technique. The open circles on 15-cm isohyet are required to be rubbed off along with dotted lines in the final map.

# 3

# Evaporation and Water Requirement

## 3.1 DETERMINATION OF EVAPORATION BY PAN EVAPORIMETER

*Theory* : Evaporation is the transfer of liquid from liquid phase to vapour state. This is a major part of a hydrologic cycle. It occurs from the surface of oceans, rivers, lakes, ponds or reservoirs, snow, soil, etc., i.e., from almost all surfaces situated on the earth. The rate varies from ocean to lake or lake to soil surface. It has been observed that 600 kcal is needed to evaporate a kilogram of water from the surface of a pond.

The major factors influencing the evaporation and their resultant effect on free water surface (such as lake) may be explained through the following empirical relation :

$$\left.\begin{aligned}\text{Evaporation} &= 0{\cdot}0024\,(e_s - e_8)v_8 \text{ inch/day}\\ &= 0{\cdot}0014986\,(e_s - e_8)v_8 \text{ cm/day}\end{aligned}\right\} \qquad (3.1)$$

where $e_s$ is the vapour pressure in inches(cm) of mercury at the water surface, $e_8$ is the same as $e_s$ but at 8 m above the water surface and $v_8$ is the wind velocity in mph(kmph) at 8 m above the water surface.

It is very difficult to determine exactly the evaporation loss from each of the surfaces listed above. So, the only alternative is to use the data of pan evaporation reduced by a suitable predetermined coefficient for each place and surface to enable one to arrive to a near-accurate result.

Evaporimeter or evaporation pan is largely used for this purpose. US Weather Bureau Class A Pan as shown in Fig. 3.1 is the most widely used evaporimeter. It is 4 feet(1·22 m) in diameter and 10 inches(25·4 cm) deep. Daily evaporation loss can be measured with a hook gauge to the nearest 0·001 inch(0·00254 cm). This is installed in the same environment from where the data is required.

Let $E_r$ be the evaporation loss from reservoir or lake and $E_p$ be the evaporation from pan. In absence of an experimental value, the ratio $E_r/E_p$ is taken as 0·67 to 0·81 to convert pan data to reservoir data.

*Materials* : US Weather Bureau Class A Pan along with all accessories, rain gauge, etc.

*Procedure* : Evaporation pan and rain gauge were installed in the manner as illustrated in Fig. 3.1 and § 2.1 at a place of our choice. With the help of hook gauge (Fig. 4.17a), the water level in the still well of pan evaporimeter was recorded daily at a fixed time. (Normally a measured volume of water is poured in pan till the water level touches the tip of the pointer fitted in the stilling well. Afterwards, this volume is suitably converted into depth.) The difference between two daily readings plus the rainfall in that period, if any, were recorded. Water was added in the evaporimeter to compensate for the loss.

The equipment was cleaned occasionally and inspected for a leakage. A crystal of copper sulphate was added once in 3–4 months to prevent any development of algae, moss, etc.

*Observations and Results* : The data are shown in Table 3.1

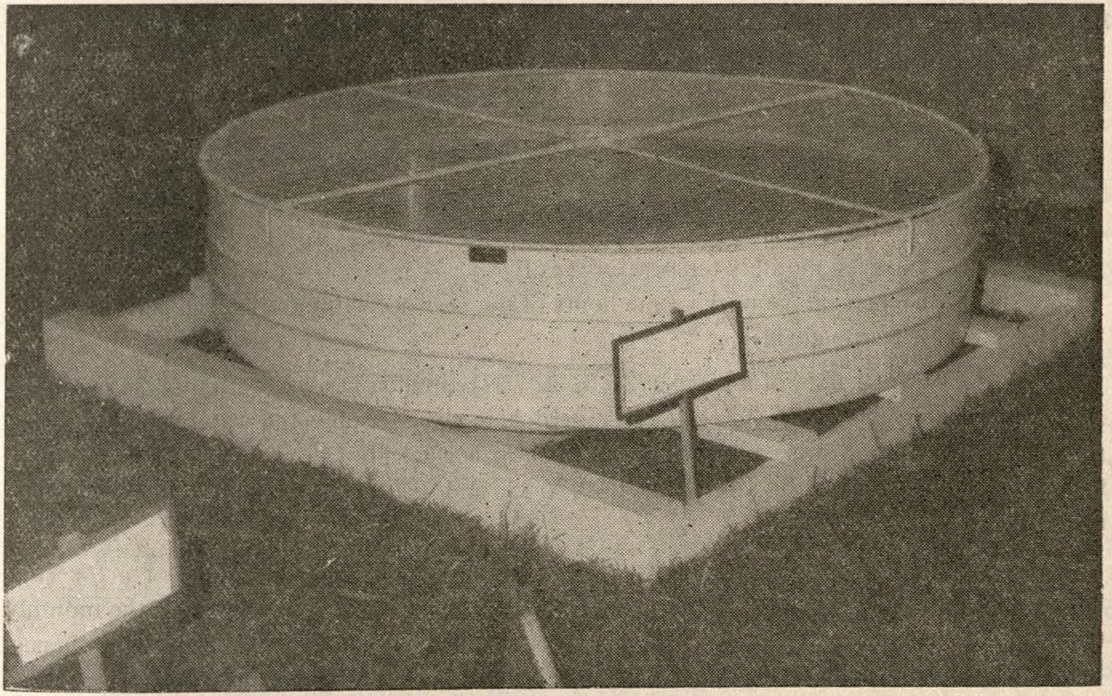


Fig. 3.1 Evaporation pan installed on a wooden plank. Vide Fig. 4.17 for some measuring devices.

Table 3.1 Evaporation data from a pan

| *Date* | *Rainfall during* 24 hr (cm) | *Recording time* | *Hook-gauge reading* (cm) | *Evaporation during* 24 hr (cm) | *Average evaporation* (cm/day) |
|---|---|---|---|---|---|
| | — | 3·10 PM | 27·00 | NA | |
| | 1·00 | 3·10 PM | 26·90 | 1·10 | 1·15 |
| | 0·50 | 3·10 PM | 26·40 | 1·00 | |
| | 0 | 3·10 PM | 25·05* | 1·35 | |

* After this the hook-gauge reading was brought back to the level of 27 cm by adding water.

Assuming $\frac{E_r}{E_p}=0{\cdot}7$, evaporation from the reservoir surface is obtained as 0·7(1·15) cm per day or 0·835 cm/day.

## 3.2 CONSUMPTIVE USE AND WATER REQUIREMENT OF A CROP

### 3.2.1 DETERMINATION OF CONSUMPTIVE USE AND WATER REQUIREMENT OF A CROP BY BLANEY-CRIDDLE METHOD.

*Theory* : Blaney-Criddle relation $u=\sum_{1}^{12} Kf$ (3.2)

where $u$=consumptive use in inch

$f$=monthly consumptive use factor=$\frac{tp}{100}$

$t$=mean monthly temperature in °F

$p$=percentage of day time hours of the year occurring during the period

$K$=crop coefficient

*Data* : Weather data of a place (72·7°E, 22·7°N) situated at an elevation of 34 m above MSL and shown in Table 2.2 (§ 2.2) is used here to determine the water requirement of sugarcane. The month-wise average values of crop coefficients ($K$) are given as 0·75, 0·80, 0·85, 0·85, 0·90, 0·95, 1·0, 1·0, 0·95, 0·90, 0·85 and 0·75 from January to December, respectively.

*Procedure* : Following the Blaney-Criddle formula (Eq 3.2), the value of $u$ for each month was calculated and water requirement was determined as ($u-R$), where $R$ is the monthly rainfall. In the months of July, August and September, ($u-R$) were negative and hence, excluded from the yearly total, because the excess amount of water available in these three months might not be retained in the soil profile for its use by the plants in subsequent months.

*Calculations and Results* : Table 2.2 gives the rainfall in mm which is converted into inch and shown in 7th column of Table 3.2. The mean monthly temperature in °C is converted to °F following conversion formula, Eq (2.2)

These conversions are necessary because the Blaney-Criddle formula holds good for such units.

Table 3.2

| *Month* | $t$ °F | $p$ | $f=\frac{tp}{100}$ | $K$ | $u$ (inch) | $R$ (inch) | *Water requirement* $(u-R)$ (inch) |
|---|---|---|---|---|---|---|---|
| Jan | 65·39 | 9·5 | 6·21 | 0·75 | 4·66 | 0·020 | 4·64 |
| Feb | 69·89 | 10·1 | 7·06 | 0·80 | 5·65 | 0·015 | 5·63 |
| March | 77·00 | 10·0 | 7·70 | 0·85 | 6·55 | 0·040 | 6·51 |
| April | 83·66 | 10·4 | 8·70 | 0·85 | 7·40 | 0·090 | 7·31 |
| May | 86·45 | 10·9 | 9·42 | 0·90 | 8·48 | 0·130 | 8·35 |
| June | 83·66 | 8·2 | 6·86 | 0·95 | 6·52 | 5·090 | 1·43 |
| July | 79·34 | 4·3 | 3·41 | 1·00 | 3·41 | 10·430 | — |
| Aug | 77·45 | 3·7 | 2·87 | 1·00 | 2·87 | 10·430 | — |
| Sept | 77·27 | 6·9 | 5·33 | 0·95 | 5·06 | 6·390 | — |
| Oct | 78·08 | 9·6 | 7·50 | 0·90 | 6·75 | 0·410 | 6·34 |
| Nov | 73·40 | 9·3 | 6·83 | 0·85 | 5·81 | 0·590 | 5·22 |
| Dec | 68·36 | 9·1 | 6·22 | 0·75 | 4·67 | 0·130 | 4·54 |
|  |  |  |  |  | $\Sigma 67{\cdot}82''$ |  | $\Sigma 49{\cdot}97''$ |

Hence, yearly $u=67{\cdot}82'' \simeq 172{\cdot}26$ cm

Yearly water requirement$=49{\cdot}97''=131{\cdot}24$ cm

### 3.2.2. DETERMINATION OF POTENTIAL EVAPOTRANSPIRATION AND WATER REQUIREMENTS OF A CROP BY THORNTHWAITE METHOD.

*Theory* : The straight line relationship obtained on a logarithmic plot by joining the index point (16·6, 26·6) and heat index (1·6, 13·67) $\frac{1}{10}\sum_{1}^{12} i$, where $i=\left(\frac{t}{5}\right)^{1.514}$ (3.3)

forms the basis of determination of consumptive use and water requirement of a crop by Thornthwaite method. Corresponding to the mean monthly temperature, $t$ °C, of a given place, the monthly consumptive use, $u_1$ cm, is obtained from the straight line plot. The potential monthly consumptive use ($u$ cm) is then obtained as $fu_1$, where $f$ is a correction factor related to the latitude of the place.

*Data* : The data of Table 2.2(§ 2.2) along with the data of Table 3.2(§3.2.1) are used here.

*Procedure* : Using Eq (3.3), the $i$-values were calculated. The value of $\overset{12}{\underset{1}{\Sigma}}\, i$ was obtained as 136·6813. Accordingly, the heat index point (1·6, 13·67) and the given index point (16·6, 26·6) were plotted and joined by a straight line (Fig. 3.4). Based on this line corresponding to each monthly temperature, $u_1$ cm for all the twelve months were found out (Table 3.3). Interpolating the data of $f$ for 20°N and 30°N as given in Israelsen and Hansen (1962)‡ the value of $f$ for 22·7°N was obtained for the present location. Accordingly, $u=fu_1$ cm was calculated. The amount of rainfall ($R$ cm) was deducted to determine monthly water requirements.

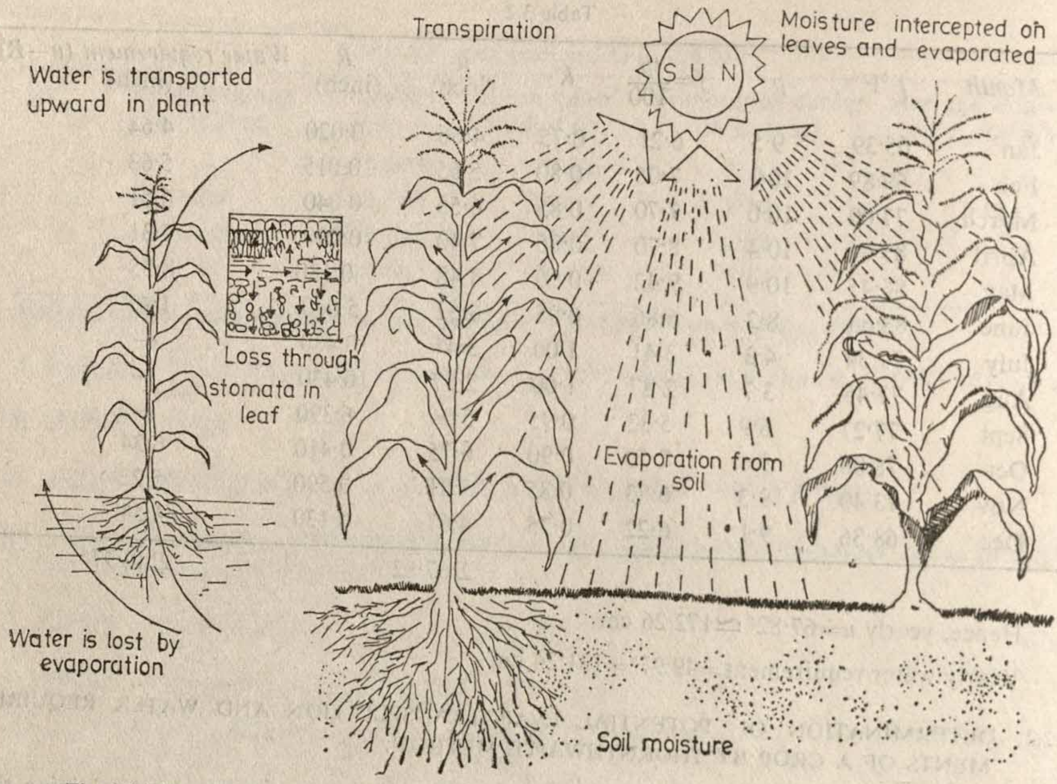

Transpiration
S U N
Moisture intercepted on leaves and evaporated
Water is transported upward in plant
Loss through stomata in leaf
Evaporation from soil
Water is lost by evaporation
Soil moisture

Fig. 3.2 Pictorial view of the consumptive use which is the summation of transpiration from plants and evaporation from the adjacent soil and plant surfaces.

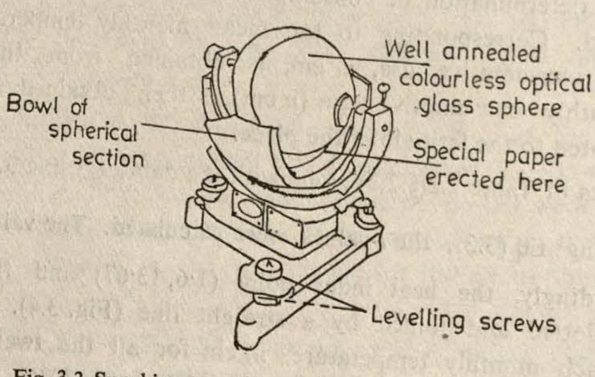

Well annealed colourless optical glass sphere
Bowl of spherical section
Special paper erected here
Levelling screws

Fig. 3.3 Sunshine recorder to obtain day-time hours.

Table 3.3 Calculation of consumptive use and water requirement by Thornthwaite method

| *Month* | *Mean tempt* ($t$ °C) | *Heat index* $i$ | $f$ | $u_1$ (cm) | $u=fu_1$ (cm) | *Rainfall* $R$ (cm) | *WR* $(u-R)$ (cm) |
|---|---|---|---|---|---|---|---|
| Jan | 18·55 | 7·2783 | 0·94 | 4·5 | 4·23 | 0·05 | 4·18 |
| Feb | 21·05 | 8·8138 | 0·89 | 6·6 | 5·87 | 0·04 | 5·83 |
| March | 25·00 | 11·4351 | 1·03 | 12·5 | 12·88 | 0·11 | 12·77 |
| April | 28·70 | 14·0927 | 1·06 | 23·0 | 24·38 | 0·22 | 24·16 |
| May | 30·25 | 15·2608 | 1·14 | 27·0 | 30·78 | 0·32 | 30·46 |
| June | 28·70 | 14·0927 | 1·13 | 23·0 | 25·99 | 12·94 | 13·05 |
| July | 26·30 | 12·3473 | 1·16 | 14·0 | 16·24 | 26·49 | −ve |
| Aug | 25·25 | 11·6087 | 1·12 | 12·7 | 14·22 | 26·49 | −ve |
| Sept | 25·15 | 11·5392 | 1·02 | 12·6 | 12·85 | 16·23 | −ve |
| Oct | 25·60 | 11·8532 | 0·99 | 15·0 | 14·85 | 1·03 | 13·82 |
| Nov | 23·00 | 10·0789 | 0·92 | 10·5 | 9·66 | 1·51 | 8·15 |
| Dec | 20·20 | 8·2806 | 0·92 | 6·4 | 5·89 | 0·32 | 5·57 |
|  |  | $\Sigma$136·6813 |  |  | $\Sigma$177·84 |  | $\Sigma$117·99 |

‡ Israelsen, O. W. and Hansen, V. E., 1962. *Irrigation Principles and Practices*, 3rd Edition. John Willey & Sons, New York, London, Page 247, Table 11.8.

Thus the annual consumptive use=171·84 cm. Water requirement of the crop=117.99 cm per year.

*Discussion* : It is noted that for July, August and September, the rainfall is more than the consumptive use. This excess amount of water is likely to be lost as runoff, deep percolation and/or other types of losses. In other words, the soil profile may not be in a position to retain this excess amount of water for subsequent use by crops during the months of October to December. Hence, $(u-R)$ for July to September were kept outside the yearly summation.

The main limitation of this method is that it does not consider any crop factor which is very relevant. Hence, variations in $u$ values from one crop to another are not possible in Thornthwaite method. This is far from real situations.

It may be noted that the values of the consumptive use calculated by the two methods (Blaney-Criddle and Thornthwaite) do not differ appreciably. In general, different empirical approaches lead to different results.

Evapotranspiration $(E_T)$ plus the water required for the metabolic activities of the crop $(W_M)$ is the consumptive use $(u)$. Very often, $W_M$ is insignificant in comparison to $E_T$. Hence, $E_T$ and $u$ are often used interchangeably.

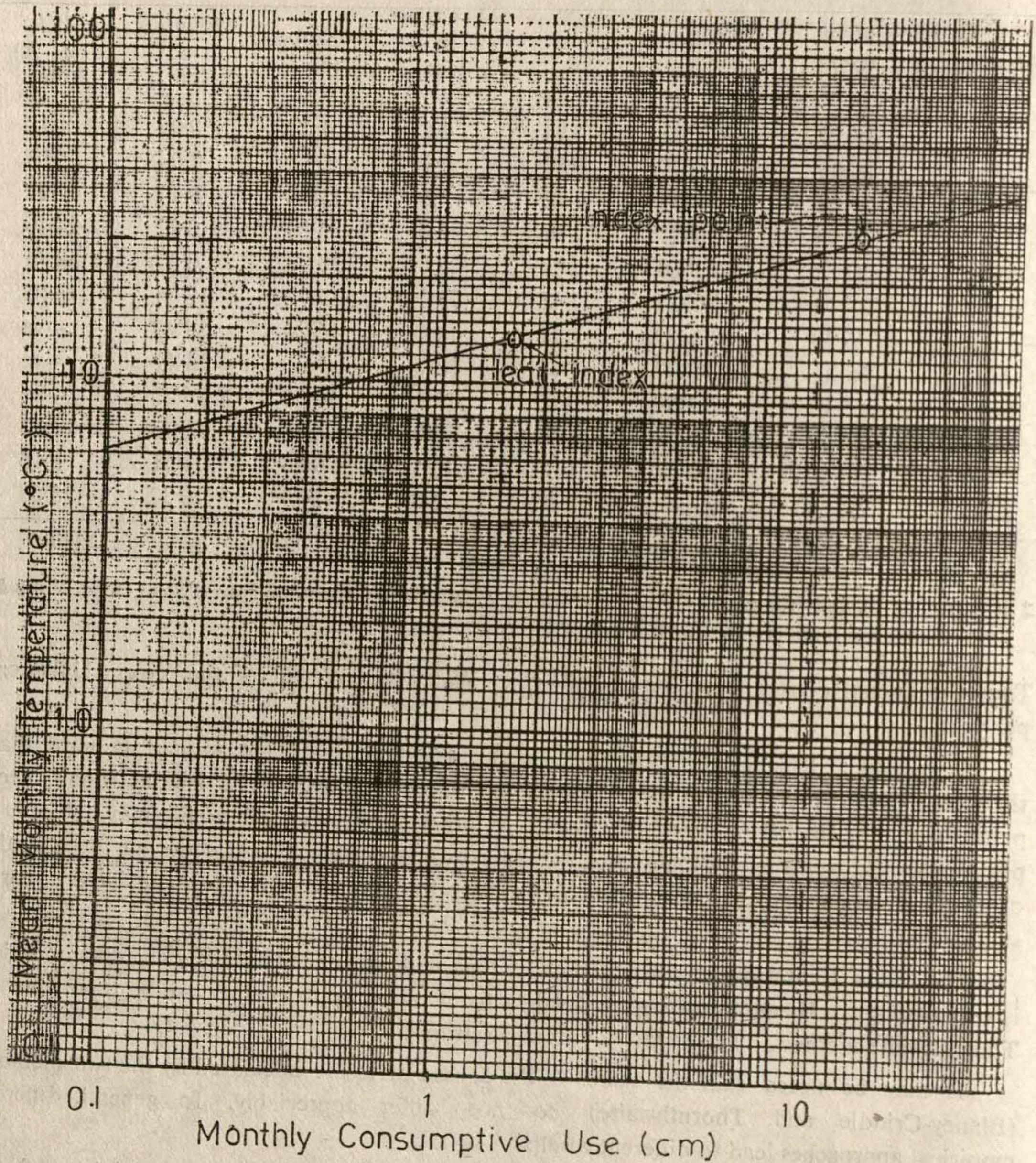


Fig. 3.4. Graphical illustration of the Thornthwaite's empirical method to determine consumptive use. The dotted lines illustrate on how to get $u_1=12{\cdot}5$ cm for March ($t=25$ °C).

### 3.2.3 DETERMINATION OF EVAPOTRANSPIRATION OF A CROP USING PAN DATA.

*Theory* : Sunken screen pan evaporimeter buried in the ground of crop environment maintaining its free water surface at the level of the ground surface gives the evaporation data which is more or less same as that of evapotranspiration of the crop.

Evapotranspiration rate ($E_T$) of upland crop is less than evaporation from free water surface or pan evaporimeter. The measurement of evapotranspiration ($E_T$) is cumbersome and time consuming, while that of evaporation is relatively easy. Moreover, the pan evaporation data ($E_p$) are widely available. The relationship between $E_T$ and $E_p$ is, therefore, developed for many regions and crops by many workers. One such relation is

$$E_T = mE_p{}^n \tag{3.4}$$

where $E_T$ is the daily evapotranspiration in cm for wheat crop ; $E_p$ is the daily evaporation in cm from USWB Class A Pan ; $m$ and $n$ are empirical coefficient and exponent to be determined '*a priori*' for a place and a crop.

In absence of any reliable value of $m$ and $n$, the values obtained in different regions but under similar conditions may be used.

*Materials* : Average evaporation data of the concerned crop for the last 10-year period.

*Procedure* : The 10-year daily average data on pan evaporation (USWB Class A Pan) were collected from the nearest meteorological station for the wheat-growing period, i.e., mid-November to February. Using Eq (3.4), the daily $E_T$ was estimated. This was multiplied by the number of days of wheat season to obtain total evapotranspiration of the crop.

*Observations and Results* : Wheat is a crop of about 110 days' duration. For about 20 days before the harvest, normally no irrigation is required. Thus, from the point of view of irrigation water supply, the estimation of $E_T$ is required to be done for 90 days only.

For the present locality and crop $m=1{\cdot}2$ and $n=0{\cdot}8$ may be taken for Eq (3.4)

Table 3.4 Values of $E_p$ and $E_T$ for wheat

| *Wheat-growing month* | *Mean tempt* (°C) | *Pan evaporation $E_p$* (mm/day) | *Daily* $E_T$ (cm) | *Total** $E_T$ (cm) |
|---|---|---|---|---|
| November | 15·6 | 2·4 | 0·3833 | $15\times0{\cdot}3833=5{\cdot}75$ |
| December | 13·0 | 2·5 | 0·3958 | $31(0{\cdot}3958)=12{\cdot}27$ |
| January | 12·5 | 2·1 | 0·3442 | $31(0{\cdot}3442)=10{\cdot}67$ |
| February | 14·2 | 3·2 | 0·4823 | $13(0{\cdot}4823)=6{\cdot}27$ |
| | | | | $\Sigma$ 34·96 |

*Total $E_T$=Number of days × daily $E_T$

# 4

# Soil Physics

## 4.1 CASTING OF A GYPSUM BLOCK

*Theory* : Gypsum block having two metallic electrodes within it and maintaining a certain gap in between can measure the electrical resistance depending on the moisture status of the block, if an appropriate measuring equipment is used. These blocks may be made of gypsum or plaster of Paris or any other suitable materials which can absorb soil moisture. The shape may be cylindrical or rectangular parallelopiped (Figs. 4.2 and 4.6).

If freshly prepared mixture of gypsum (plaster of Paris) and distilled water in right proportion is poured inside the wooden mould with two electrodes in appropriate position and kept as such for an hour, the gypsum block is prepared.

*Materials Required* : A frame of wooden mould (Fig. 4.1), flexible electric wire (coated with polyvinyl chloride) pieces in pairs, plaster of Paris, distilled water, stirrer, a pair of copper electrodes (flatened), etc.

*Procedure* : A wooden mould of rectangular shape (Fig. 4.1) and size 5·5 cm × 3·75 cm × 2 cm having smooth inside surface was taken. The two copper electrodes (3·5 cm × 1·75 cm) attached with electric wires in one end were hooked in the mould at 2 cm apart and parallel to each other. A slurry of water and plaster of Paris in 1 : 1 ratio was prepared by mixing it thoroughly with stirrer and poured in the mould to fill it to the brim in one stroke. The mould was then gently tapped to remove entrapped air bubbles. This was kept as such for about 60 minutes. Afterwards, the block was removed from the mould and kept in a shade for about a fortnight for curing.

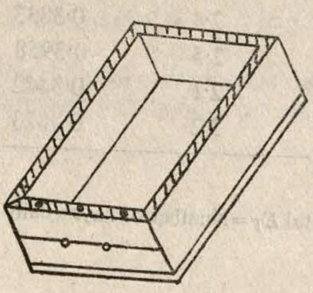


Fig. 4.1 A line sketch of a wooden mould to be used in gypsum block casting.

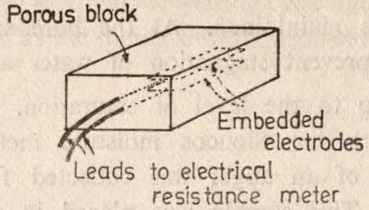


Fig. 4.2 A gypsum block after casting in a rectangular mould similar to Fig. 4.1. Vide also Fig. 4.6.

*Observations and Results* : The block of the size and shape as depicted in Fig. 4.2 is obtained.

*Note* : At a time several mould compartments could be used to cast a number of gypsum blocks simultaneously.

## 4.2 STANDARDISATION AND CALIBRATION OF GYPSUM BLOCKS

*Theory* : Gypsum blocks cast in a laboratory (§4.1) may possess encapsulated air which is required to be removed through standardisation. Standardisation is a process in which blocks are dipped into water for half an hour and then exposed to the air for ten minutes.

The process is repeated several times without any discontinuity and till all encapsulated air is removed.

Calibration means the comparison of the measuring scale (in resistance unit) of a gypsum block with those of the soil moisture content (%) determined by any reliable method.

It may be noted that depending on the soil, quality of gypsum or plaster of Paris, casting variations, etc., the calibration curve will differ. Hence, for each individual combination the block must be calibrated before use for better result.

*Materials Required* : Electrical resistance meter or Bouyoucous/Sioucos/Universal moisture meter, garden pot, small soil auger, moisture boxes, drying oven, a bucket of water, etc.

*Procedure* : (i) *Standardisation* : The blocks were dipped into the bucket full of water and kept as such for half an hour. Afterwards, these were taken out and exposed to the atmosphere for about 10 minutes. The process was repeated for 3 to 4 times.

The wire leads were connected to the Sioucos moisture meter (Fig. 4.7). The resistance in ohms was noted while the blocks were in water. When the resistance readings showed more than 5% deviation from the mean resistance readings obtained from the rest, the blocks were rejected.

(ii) *Calibration* : Garden pots previously filled with soil were taken. In each pot a hole was made with the help of a soil auger up to 15 cm depth. A block was placed in each of these bore holes and was filled with the soil and pressed for the intimate contact between the block and soil. Care was taken to remove root pieces, pebbles, etc., from the soil adjacent to the blocks. While filling back the bore the natural or *in situ* order of the soil was maintained. At the bore spot soil was heaped up to a height of 3 cm or more to prevent stagnation of water at or over the bore spot.

The pot was irrigated up to the level of saturation. After a period of 48 hours the resistance was noted with the Sioucos moisture meter (Fig. 4.7). Simultaneously, a soil sample with the help of an auger was collected from the same depth of the block and very close to it. This sample was placed in a moisture box and the bore created was filled in by the pot soil. The moisture content of sample was determined by gravimetric method (§4.3.1). The entire process was repeated for every 24 hours till a set of 7 to 10 observations was obtained. In order to facilitate the drying process this experiment was conducted in dry season. The whole process was repeated thrice and an average of the data on resistance and moisture content was considered for fitting in a calibration curve (Fig. 4.3).

*Experimental Data* : The data set for one block is reported herein (Table 4.1).

Table 4.1 Observations on moisture content against the resistance of a gypsum block

| *Resistance* (ohms) | | | | *Moisture Content* (%) | | | |
|---|---|---|---|---|---|---|---|
| *1* | *2* | *3* | *Average* | *1* | *2* | *3* | *Average* |
| 490 | 500 | 510 | 500 | 49·00 | 51·00 | 50·00 | 50·00 |
| 815 | 800 | 785 | 800 | 19·25 | 19·50 | 19·75 | 19·50 |
| 1830 | 1800 | 1770 | 1800 | 17·00 | 17·50 | 18·00 | 17·50 |
| 2990 | 3000 | 3010 | 3000 | 15·05 | 15·00 | 14·95 | 15·00 |
| 3900 | 3800 | 3700 | 3800 | 13·25 | 13·50 | 13·75 | 13·50 |
| 4750 | 4700 | 4650 | 4700 | 11·75 | 12·00 | 12·25 | 12·00 |
| 6025 | 6000 | 5775 | 6000 | 10·20 | 10·25 | 10·30 | 10·25 |
| 6780 | 6700 | 6620 | 6700 | 9·25 | 10·00 | 10·25 | 10·00 |
| 7600 | 7500 | 7400 | 7500 | 8·40 | 8·50 | 8·60 | 8·50 |
| 8040 | 8000 | 7960 | 8000 | 7·30 | 7·50 | 7·70 | 7·50 |
| 8000 | 9000 | 8200 | 8400 | 11·00 | 10·00 | 10·50 | 10·50 |

*Results* : The data are plotted and shown in Fig 4.3. The point (8400, 10·50) is far off from the remaining and hence, it is rejected. All other data points are joined by a smooth free-hand curve which is known as the 'calibration curve'.

This block is now fit for installation in any soil. The resistances may be noted according to the need. Using this calibration curve (Fig. 4.3) the resistance values may be converted into the % moisture content of the soil.

The moisture content lower than 7·5% is available from this curve, if extended.

*Note* : (i) In the field generally two blocks at a vertical distance of less than 30 cm are not placed. In one bore normally 4-5 blocks can be placed (vide Fig. 4·8).

(ii) In crop field, blocks should be placed in the root zone. To avoid hinderances to interculture operations, the blocks are placed along the row in between the plants.

(iii) Calibration should also be done for wetting cycle and the average of the two (drying and wetting cycles) will be taken as the standard calibration curve.

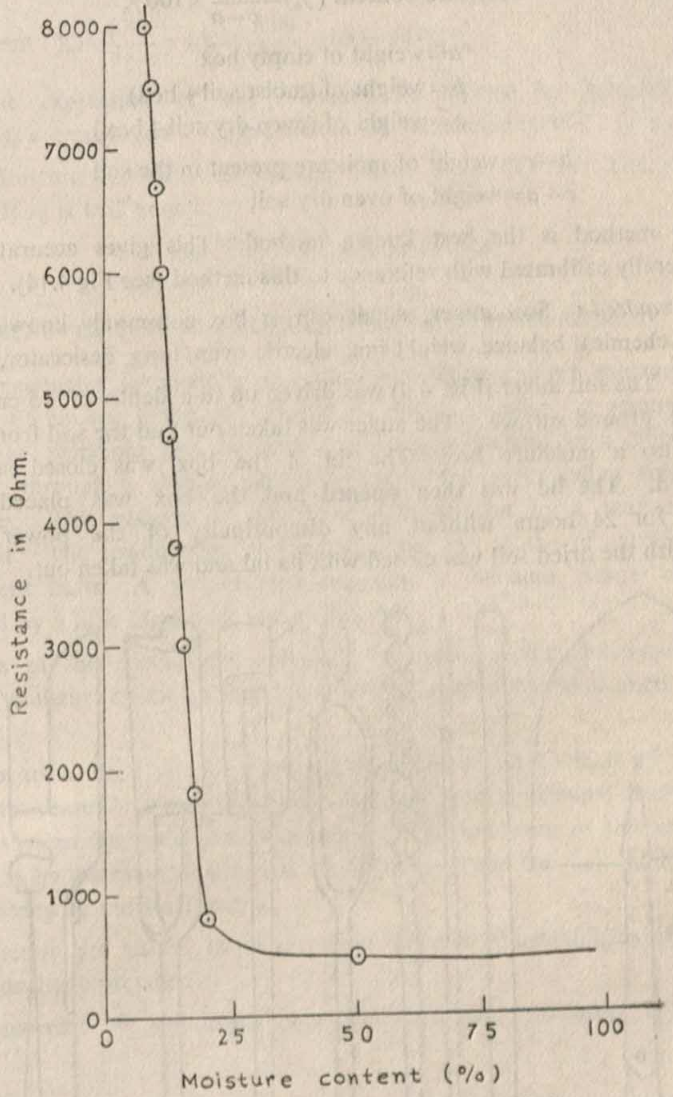


Fig. 4.3 Calibration curve of a gypsum block.

## 4.3 SOIL MOISTURE CONTENT

### 4.3.1 DETERMINATION OF SOIL MOISTURE CONTENT BY GRAVIMETRIC METHOD

*Theory* : It is usually expressed in per cent and is a ratio of the weight of moisture present in the soil to the oven dry weight of the soil. Thus

$$\text{Moisture content } (\%) = \frac{b-c}{c-a} \times 100\,\%$$

where

$a$=weight of empty box
$b$=weight of (moist soil+box)
$c$=weight of (oven dry soil+box)

Thus

$b-c$=weight of moisture present in the soil
$c-a$=weight of oven dry soil

Gravimetric method is the best known method. This gives accurate results. Other methods are generally calibrated with reference to this method (see Fig 4.14).

*Apparatus required* : Soil auger, small can or box commonly known as 'soil moisture box', physical or chemical balance, weight box, electric oven, tong, desiccator, etc.

*Procedure* : The soil auger (Fig. 4.4) was driven up to a depth of 15 cm (or any desired depth) from the ground surface. The auger was taken out and the soil from the bottom end was collected into a moisture box. The lid of the box was closed soon after. This box was weighed. The lid was then opened and the box was placed in an electric oven at 105 °C for 24 hours without any discontinuity of the power supply. Afterwards, the box with the dried soil was closed with its lid and was taken out.

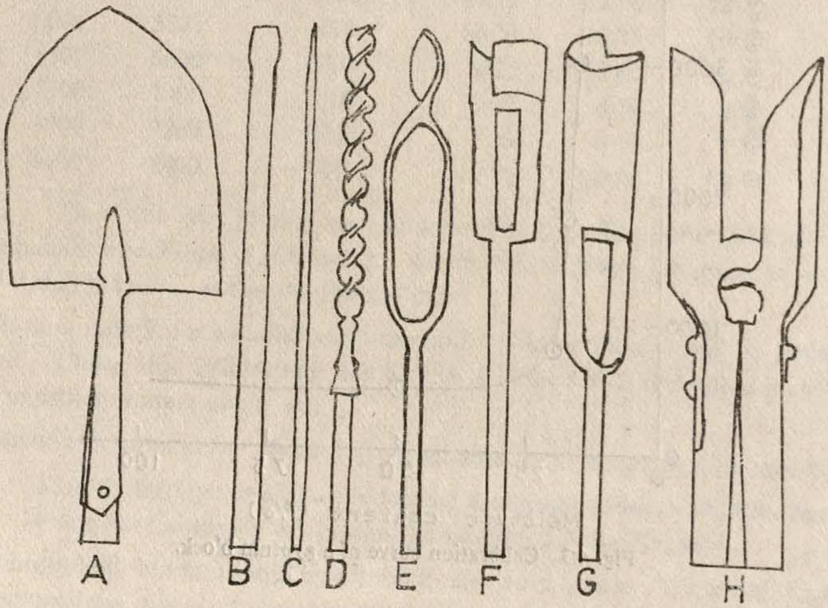


Fig. 4.4 Soil augers. *C* or *D* type augers are good for small collections.

To cool, this was placed in a desiccator for about 10-15 minutes. The box plus dry soil was then weighed. The soil was thrown out to make the box empty. The weight of empty box was taken (see Fig. 4.14).

*Observations and Results* : $b=35{\cdot}50$ gm

$c=32{\cdot}60$ gm

$a=12{\cdot}90$ gm

$$\text{Moisture content }(\%)=\frac{b-c}{c-a}\times 100=\frac{2{\cdot}90}{19{\cdot}70}\times 100=14{\cdot}72\%$$

*Remark* : The expression of soil moisture as volume by volume or volumetric moisture content ($\theta$) is considered a comparatively better method (§ 4.7). It is as follows :

$\theta=\frac{1}{100}\,\rho_b$ (Moisture content, %) vol/vol, where $\rho_b$ is the dry bulk density of the soil (vide § 4.6). If $\rho_b$ is 1·52 gm/c.c.

$$\theta=\frac{1{\cdot}52(14{\cdot}72)}{100}=0{\cdot}22 \text{ vol/vol}$$

### 4.3.2 DETERMINATION OF SOIL MOISTURE CONTENT BY TENSIOMETER

*Theory* : Tensiometer installed in a soil up to a chosen depth measures soil moisture tension in terms of cm (or inch) of mercury or water column or atmospheric pressure. This works on the principle that a partial vacuum is created in a closed chamber and water moves out through a porous ceramic cup to the surrounding soil, if the soil is dry or vice versa. This vacuum is measured as a tension by a manometer or vacuum gauge fitted in it. The graduation of the gauge is in $\frac{1}{100}$th of atmospheric pressure or some equivalent units. A porous clay cup and a vacuum gauge or a manometer are interconnected by a tube filled with water (Fig. 4.5).

The readings of the tensiometer obtained in terms of the above-mentioned units are converted into % moisture content using a calibration curve of the tensiometer in use (Fig. 4.9 or Eq 4.1).

It works up to a limit of 0·8 atmospheric pressure after which air enters the system and the tensiometer ceases to work. Increase in gauge reading means decrease in moisture content of the surrounding soil and vice versa. The tendency of the water in the porous cup and the tube is to maintain a dynamic equilibrium with the soil adjacent to the cup from the point of view of moisture status.

The tensiometers are useful in sandy soils wherein about 80% available water is held within 0–0·8 atmospheric pressure.

*Apparatus required* : A soil auger (Fig. 4.4), hammer, tensiometer (Fig. 4.5), coloured stakes, etc.

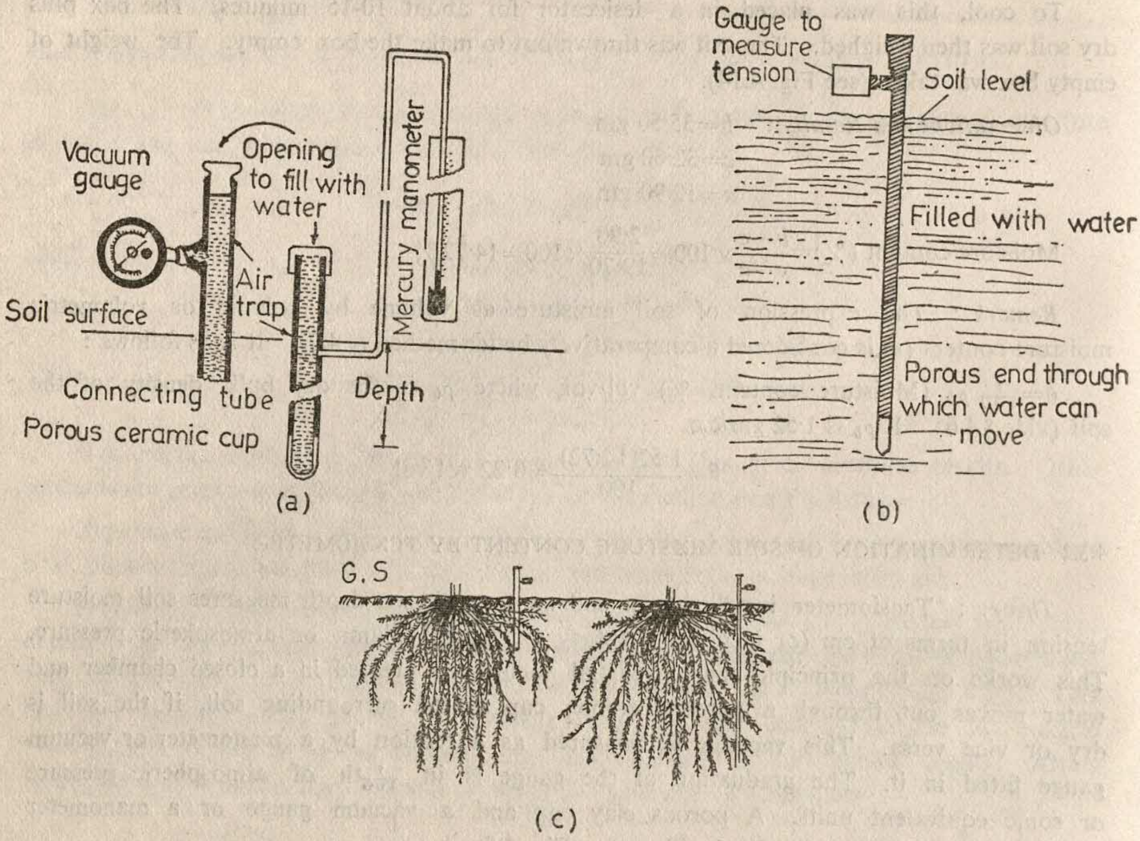


Fig. 4.5 Tensiometer (*a*) cross-sectional view ; (*b*) installed in the field ; (*c*) installed in the crop root zone.

*Procedure* : The tensiometer was checked before its installation in the field. In order to know the air-tightness of the system, the tube (Fig. 4.5 *a*, *b*) was filled with boiled water and corked. It was then held above a hot plate. The gauge reading was increasing with the evaporation of moisture or water from the cup surface till at least 0·85 atmosphere (if the system would have been defective, the needle would have moved back before it reached 0·85 atmosphere showing the leakage). The tensiometer was then immersed in free water and after some time the reading was noted as zero.

A spot in the crop field was selected in such a manner that it does not hamper the normal field operations (Fig. 4.5 *c*). A bore hole up to a desired depth was made by a soil auger. The tensiometer was inserted into the hole. The walls of the cup and the soil were kept in intimate contact with each other. Care was taken to ensure that the hole diameter coincides approximately with the diameter of the tensiometer tube. Soil was compacted around the stem of the tensiometer near the ground surface and a heap of soil about 4 cm high was made to check water collection around the stem and to prevent its flow directly through the body of the tensiometer. Area surrounding the tensiometer was enclosed by a circular bracketing with coloured stakes. Some thorns were also placed around it.

After about 48 hours of the installation the readings were taken regularly from 0700 hours. Using Eq (4.1) or the calibration curve for the tensiometer and soil (Fig. 4.9) the tension readings were converted to % moisture content of the soil.

*Observations and Results* : These are shown in Table 4.2

Table 4.2 Tensiometric data

| *Date* | *Time hours* | *Tension atmos* | *Tension* cm *Mercury* | *Moisture content from* Fig. 4.9 % |
|---|---|---|---|---|
| | 0600 | 0·30 | 22·8 | 14·5 |
| | 1000 | 0·32 | 24·3 | 14·2 |
| | 1400 | 0·35 | 26·1 | 13·7 |
| | 1800 | 0·42 | 31·9 | 12·7 |

*Salient Points* : (i) The effective root zone changes in a growing crop field. The depth of installation, therefore, is required to be changed suitably with the growth of the crop, if the readings are required from root zone depth.

(ii) The difference between two consecutive tensiometer readings should not exceed 10 centibars.

(iii) If $D$ be the root zone depth of the crop, it is then suggested to measure moisture contents at the ground surface, $0{\cdot}25D$, $0{\cdot}5D$, $0{\cdot}75D$ and $D$. An average of these may be considered as moisture content in the root zone. Sometimes five measurements at a single vertical column become laborious and time consuming. Alternatively, measurements only at $0{\cdot}25D$ and $0{\cdot}75D$ are considered sufficient. Ordinarily, depths at 15, 30 and 45 cm are assumed as good enough for soil moisture measurements in a crop field. Vide Figs. 4.5*c* and 4.8

### 4.3.3. DETERMINATION OF SOIL MOISTURE BY GYPSUM BLOCK

*Theory* : In a gypsum block there are two metallic electrodes at a certain distance apart. This gap is filled up with gypsum. The moisture status of gypsum goes on changing with the moisture content of the adjacent soil. Thus if a constant electric current is passed through the circuit of the gypsum block the current from one electrode to another will have to pass through a gypsum body in between offering certain resistance which will vary depending on the moisture present therein. This variable resistance can be measured accurately by Wheatstone Bridge method or by using any resistance meter, viz., Bouyoucos or Sioucos moisture meter (Fig. 4.7). Using a calibration curve (Fig. 4.3) the readings of resistance can be converted to % moisture content of the soil. In a moisture meter sometimes both the scales of resistance in ohm and moisture content in % are provided by the manufacturer. Hence directly from the meter reading the moisture status (%) can be known.

A gypsum block is good for soil moisture tension more than one atmosphere.

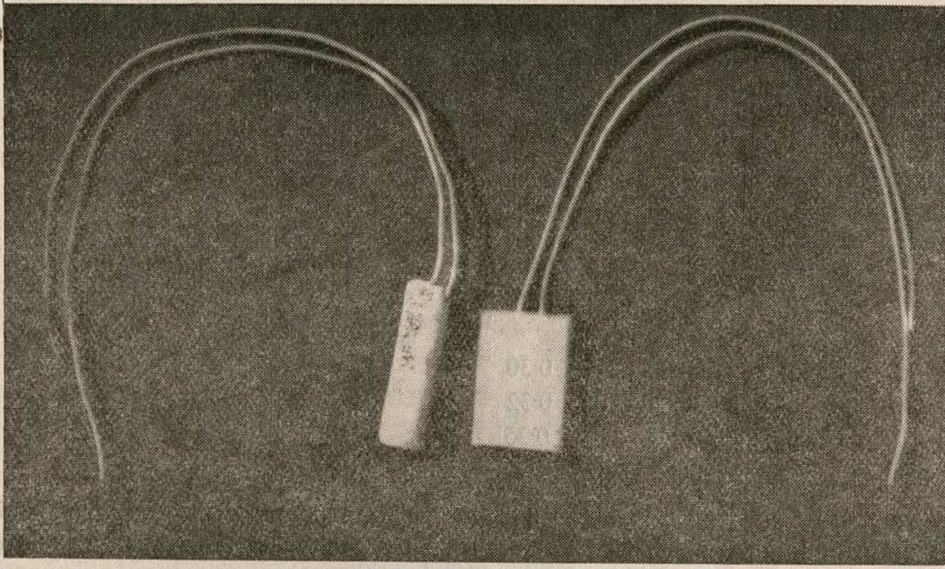


Fig. 4.6

Rectangular and cylindrical shaped gypsum blocks along with wire connections. The two open ends of the wires may be connected with the two nobs of the moisture meter to record the reading. Vide also Fig. 4.2.

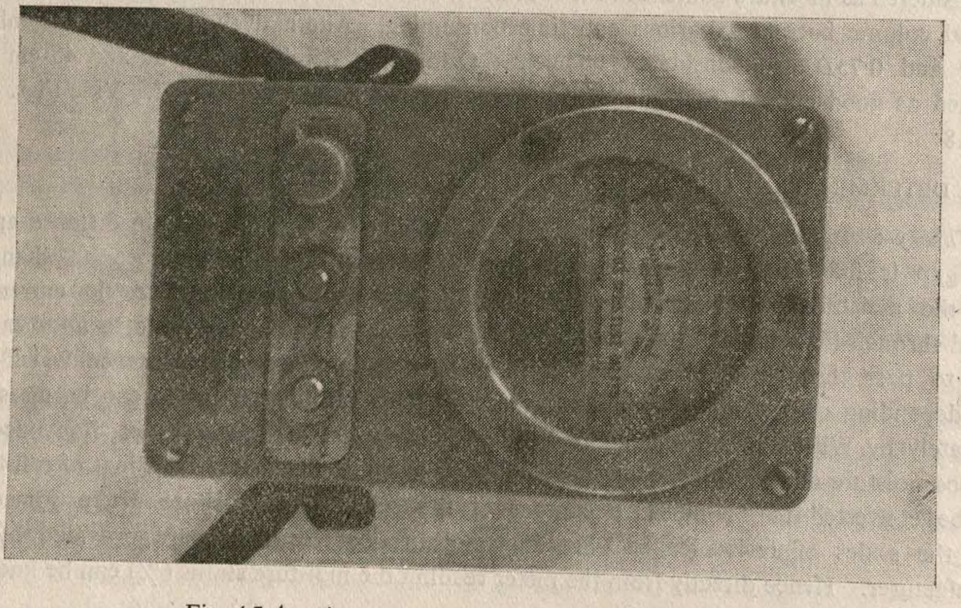


Fig. 4.7 A moisture meter to be used with gypsum blocks

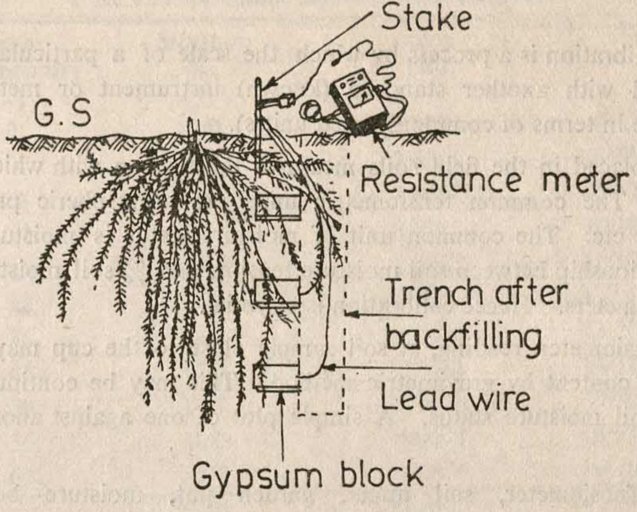


Fig. 4.8 Gypsum blocks placed at three different depths in the root zone of a crop and the complete electric connections with the moisture meter.

*Apparatus required* : A gypsum block of any size and shape (Fig. 4.6) ; moisture meter (Fig. 4.7) ; soil auger (Fig. 4.4).

*Procedure* : A soil auger was driven to a desired depth (vide last para in § 4.3.2) and was taken out. A gypsum block fitted with all electric connections was inserted in that depth (Fig. 4.8). The hole was then filled up slowly by putting soil into it and by mild compaction. It was left as such for at least 3 days. Afterwards, the moisture meter (Fig 4.8) was connected with the block. The switch of the meter specified for this was pushed and the reading against the pointer was read. The block was kept as such for further measurement at any chosen date and time.

*Observations & Results* : Reading against the pointer is 20·7%. Hence the moisture content of the soil at the time of recording was 20·7%.

*Note* : (i) In a tensiometer gauge similar to the gauge of a moisture meter both the scales of resistance and % moisture content are sometimes provided. Hence without using a calibration curve moisture content in % can be had from a tensiometer also.

(ii) The scale on moisture content (%) provided in a moisture meter or in a tensiometer gauge is good for general purposes and rough approximation. For micro-scale work one such scale cannot hold good for all soils, gypsum blocks or tensiometers. Thus calibration for each combination of soil, gypsum block or tensiometer is required. It may also be remembered that a gypsum block deteriorates in one to three seasons of continuous use. Hence the calibration curve of a gypsum block may change with the advancement of time, the other things remaining same.

## 4.4. CALIBRATION OF A TENSIOMETER

*Theory* : Calibration is a process by which the scale of a particular measuring instrument is compared with another standard (known) instrument or method in order to get the measured value in terms of commonly used unit(s).

Tensiometer placed in the field soils measures the tension with which water or moisture is held in soils. The common tensiometric units are atmospheric pressure, bar, cm of mercury or water, etc. The common unit of moisture status is moisture content in % by weight. The relationship between soil moisture tension and % soil moisture is not same for all soils and tensiometers. Hence calibration is essential.

For each tensiometer reading, a soil sample close to the cup may be taken to determine its moisture content by gravimetric method. This may be continued for at least five widely different soil moisture status. A simple plot of one against another will yield a calibration curve.

*Materials* : Tensiometer, soil auger, garden pot, moisture boxes, drying oven, water, etc.

*Procedure* : Following the procedure outlined in § 4.3.2 a tensiometer was installed at a desired depth in a garden pot full of soil. A certain volume of water was poured in the pot to make the soil just saturated. After 48 hours the reading of the tensiometer was noted. Simultaneously a small soil sample was collected from the same depth as that of tensiometer cup and very close to it. The moisture content of this sample was determined by gravimetric method (§ 4.3.1). The process was continued for every consecutive day in the drying cycle of the pot-soil. Accordingly, a set of data on tension (cm of mercury) versus moisture content (%) was obtained. The data thus obtained were plotted in squared (Fig. 4.9) as well as in semi-log graph papers (Fig. 4.10). An equation (Eq 4.1) was fitted to this data set, following least square method.

*Observations & Results* : The experimental data are tabulated in the 2nd & 3rd columns of Table 4.3. The 4th, 5th & 6th columns show the method of data processing to fit in Eq (4.1).

Table 4.3 Experimental data & other calculations

| *Serial No.* | *Tension* cm of mercury ($x$) | *Moisture* % ($y$) | ln $x$ ($X$) | $X^2$ | $Xy$ |
|---|---|---|---|---|---|
| 1 | 9 | 19·0 | 2·1972 | 4·8278 | 41·7473 |
| 2 | 14 | 17·0 | 2·6391 | 6·9646 | 44·8639 |
| 3 | 20 | 15·0 | 2·9957 | 8·9744 | 44·9360 |
| 4 | 24 | 14·2 | 3·1781 | 10·1000 | 45·1284 |
| 5 | 28 | 13·5 | 3·3322 | 11·1036 | 44·9848 |
| 6 | 32 | 12·7 | 3·4658 | 12·0113 | 44·0148 |
| 7 | 38 | 11·7 | 3·6376 | 13·2320 | 42·5598 |
| 8 | 44 | 11·5 | 3·7842 | 14·3201 | 43·5182 |
| 9 | 50 | 10·7 | 3·9120 | 15·3039 | 41·8586 |
| 10 | 55 | 10·0 | 4·0073 | 16·0587 | 40·0733 |
| 11 | 60 | 9·7 | 4·0944 | 16·7637 | 39·7151 |
| Total | | 145·0 | 37·2435 | 129·6602 | 473·4002 |

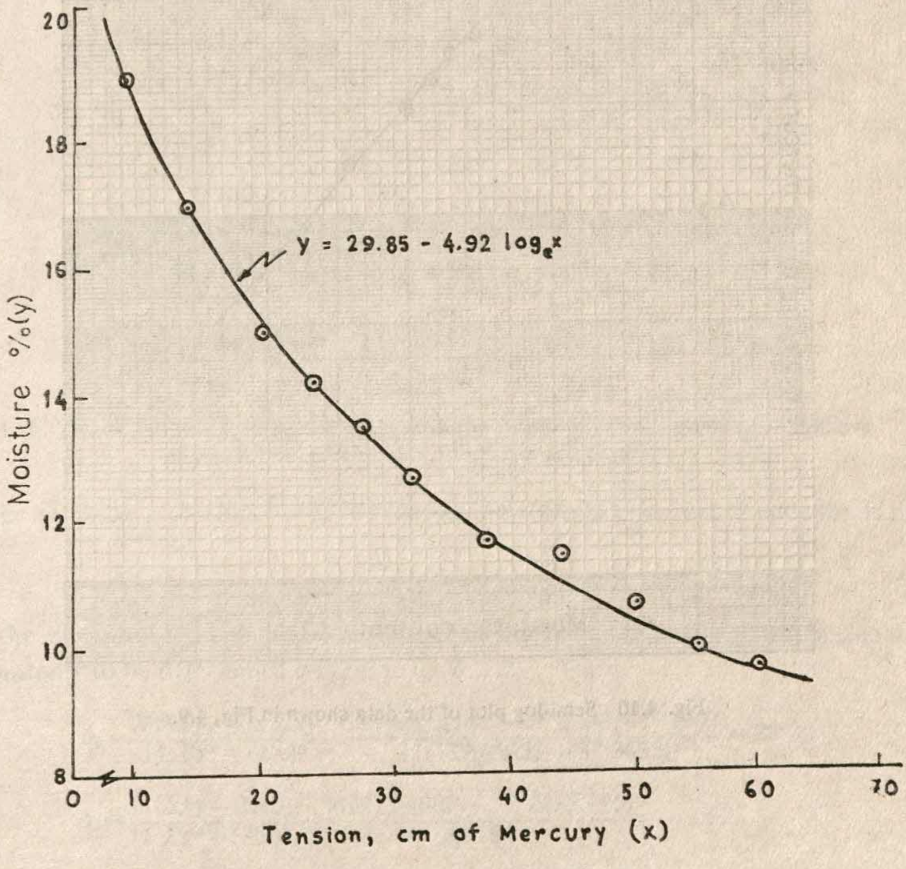


Fig. 4.9 Calibration curve of a tensiometer

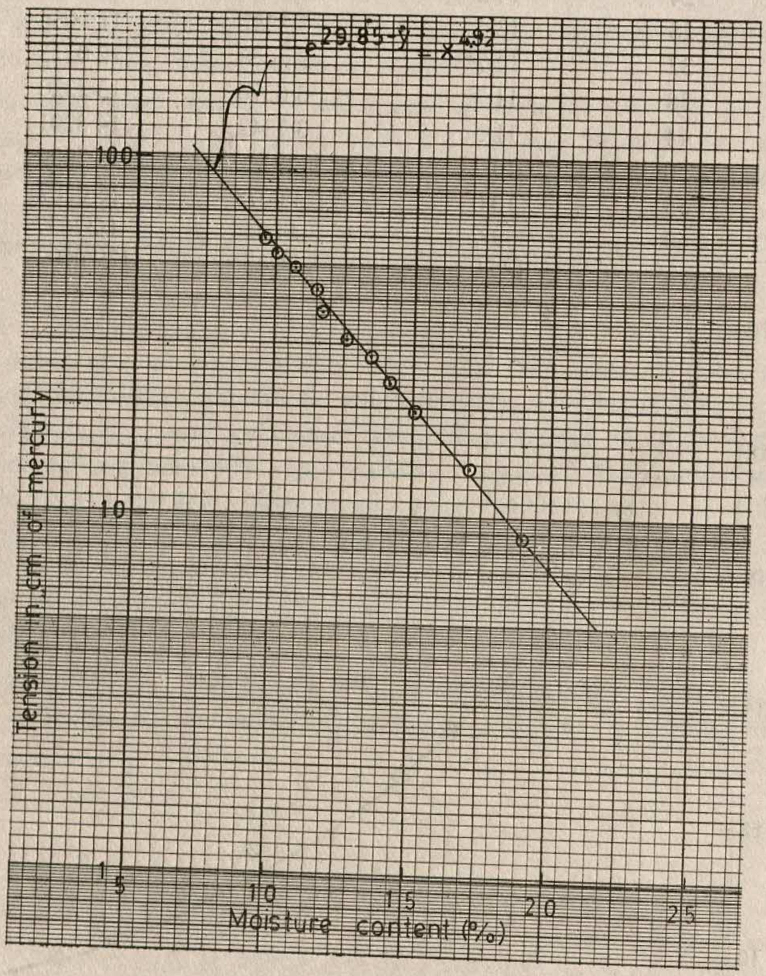


Fig. 4.10 Semi-log plot of the data shown in Fig, 4.9.

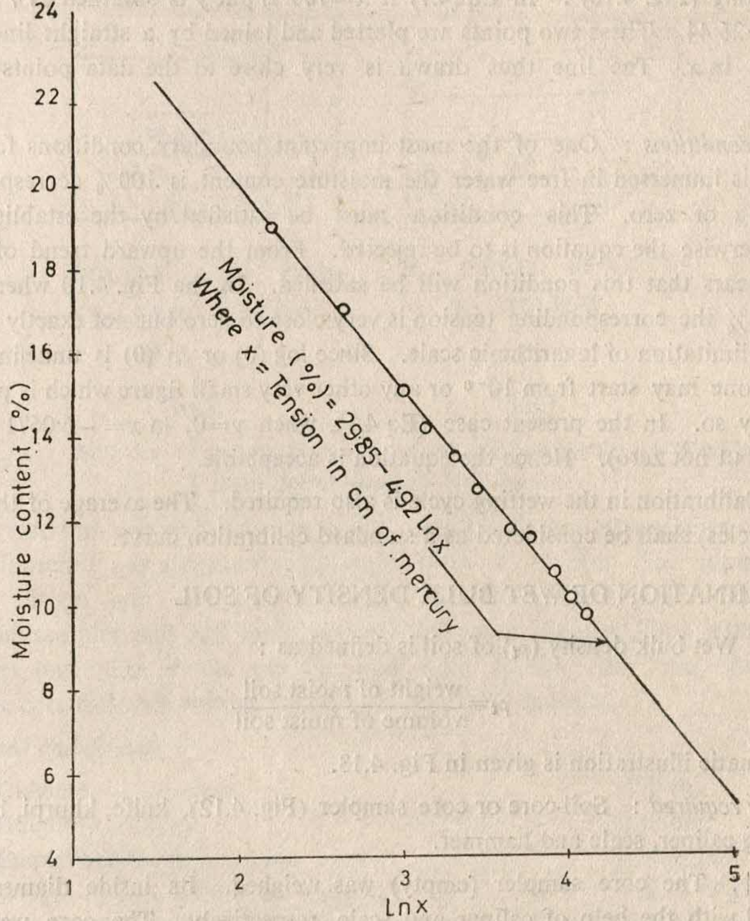


Fig. 4.11 The plot of ln $x$ versus moisture content in a squared graph paper as an alternative of Fig. 4.10 in absence of a semi-log graph paper.

From the semi-log plot (Fig. 4.10) it becomes obvious that the best fit equation is of the form :

$$y=a_0+a_1 \ln x \tag{4.1}$$

where $y$ is the moisture content of soil in %, $x$ is the tension in cm of mercury, $a_0$ and $a_1$ are empirical constants to be determined (vide Eqs 1.1 & 1.2). Thus,

$$a_0=\frac{\Sigma x^2 \Sigma y-\Sigma x\, \Sigma xy}{11\, \Sigma x^2-(\Sigma x)^2}=\frac{129\cdot6602(145)-37\cdot2435(473\cdot4002)}{11(129\cdot6602)-(37\cdot2435)^2}=29\cdot85$$

$$a_1=\frac{11\, \Sigma xy-\Sigma x \Sigma y}{11\, \Sigma x^2-(\Sigma x)^2}=\frac{11(473\cdot4002)-37\cdot2435(145)}{39\cdot184}=-4\cdot92$$

Thus $a_0$ and $a_1$ of Eq (4.1) may be replaced by 29·85 and $-4\cdot92$, respectively.

*Line Drawing* (Fig. 4.10) : In Eq (4.1) if $x=100$ is put $y$ is obtained as 7·19. Similarly when $x=2$, $y=26{\cdot}44$. These two points are plotted and joined by a straight line to represent $y=29{\cdot}85-4{\cdot}92 \ln x$. The line thus drawn is very close to the data points and hence is acceptable.

*Boundary conditions* : One of the most important boundary conditions for tensiometer is that when it is immersed in free water the moisture content is 100% corresponding to the tension reading of zero. This condition must be satisfied by the established equation (Eq 4.1). Otherwise the equation is to be rejected. From the upward trend of the curve in Fig. 4.9 it appears that this condition will be satisfied. In the Fig. 4.10 when the moisture content is 100% the corresponding tension is very close to zero but not exactly zero. This is because of the limitation of logarithmic scale. Since log (0) or ln (0) is undefined that's why in a log plot one may start from $10^{-6}$ or any other very small figure which is practically zero but not exactly so. In the present case (Eq 4.1), when $y=0$, $\ln x=-6{\cdot}0671$ or $x=0{\cdot}0023$ (close to zero but not zero). Hence the equation is acceptable.

*Note* : Calibration in the wetting cycle is also required. The average of the two (drying and wetting cycles) shall be considered as a standard calibration curve.

## 4.5 DETERMINATION OF WET BULK DENSITY OF SOIL

*Theory* : Wet bulk density ($\rho_t$) of soil is defined as :

$$\rho_t=\frac{\text{weight of moist soil}}{\text{volume of moist soil}}$$

The schematic illustration is given in Fig. 4.13.

*Apparatus required* : Soil core or core sampler (Fig. 4.12), knife, khurpi, balance, weight box, measuring caliper, scale and hammer.

*Procedure* : The core sampler (empty) was weighed. Its inside diamerer and height were measured with the help of caliper and scale, respectively. The core was then pushed into the soil (*in situ*) of our choice by hammering slowly from the top.

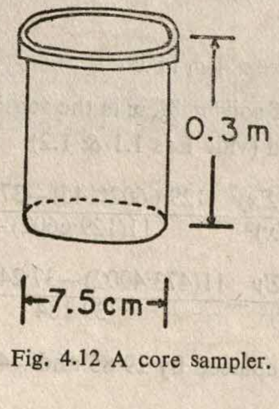


Fig. 4.12 A core sampler.

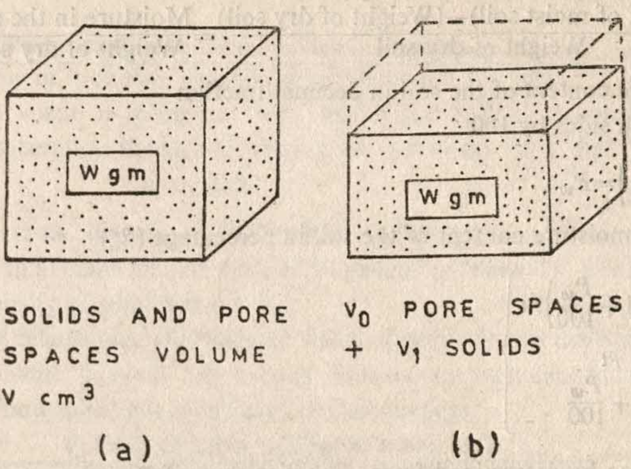

W gm
W gm
SOLIDS AND PORE SPACES VOLUME V cm3
V0 PORE SPACES + V1 SOLIDS
(a)
(b)

Fig. 4.13 Bulk density and particle density of soil ; (*a*) bulk density$=W/V$ gm/cc ; (*b*) solid particle density$=W/V_1$ gm/cc.

When the insertion was complete the soil in contact with the outer surface of the cylindrical core was loosened and displaced with the help of a khurpi. The sampler was then tilted a little bit in any direction to break up the contact plane (bottom) of the soil within the sampler and soil mass *in situ.* The core sampler filled with the field soil was then taken out. The excess soil on both ends of the core was sliced out with the knife. The core full with soil was weighed in a suitable balance.

*Observations and Results* :

| | |
|---|---|
| Diameter ($d$) of core | $=10$ cm |
| Height ($h$) of core | $=15$ cm |
| Empty weight ($W_1$) of core | $=1800$ gm |
| Weight of core with moist soil ($W_2$) | $=4073{\cdot}73$ gm |
| Weight of moist soil$=W_2-W_1$ | $=2273{\cdot}73$ gm |
| Volume of moist soil (i.e., core)$=\frac{\pi}{4}d^2h$ | $=1178{\cdot}0971$ cm$^3$ |

$$\therefore \quad \rho_t=\frac{2273{\cdot}73}{1178{\cdot}0971}=1{\cdot}93 \text{ gm/cm}^3$$

## 4.6 DETERMINATION OF DRY BULK DENSITY OF SOIL

*Theory* : Dry bulk density ($\rho_b$) of soil is defined as

$$\rho_b=\frac{\text{over-dry weight of soil}}{\text{volume of soil before drying}}$$

Alternatively, $\rho_t$ and $\rho_b$ are interrelated as

$$\frac{\rho_t}{\rho_b}=\frac{\text{weight of moist soil}}{\text{weight of over-dry soil}}$$

if the same volume of soil is considered.

$$\frac{\rho_t}{\rho_b}-1=\frac{(\text{Weight of moist soil})-(\text{Weight of dry soil})}{\text{Weight of dry soil}}=\frac{\text{Moisture in the soil}}{\text{Weight of dry soil}}$$

=Moisture content of the soil in decimal fraction

Multiplying both sides by 100

$$100\left(\frac{\rho_t}{\rho_b}-1\right)=P_w$$

where $P_w$ is the moisture content of the soil in percentage (%).

$$\left.\begin{aligned}\text{Thus } \rho_t&=\left(1+\frac{P_w}{100}\right)\rho_b\\ \text{or } \quad \rho_b&=\frac{\rho_t}{1+\frac{P_w}{100}}\end{aligned}\right\} \qquad (4.2)$$

Hence $\rho_b$ can also be determined from $\rho_t$ or vice versa if $P_w$ is known (§ 4.7).

*Experimental accessories* : Soil tray, electric oven for soil drying, soil core (Fig. 4.12), knife, khurpi, balance, weight box, measuring caliper, scale, hammer, etc.

*Procedure* : The procedure described in § 4.5 was followed. Afterwards the moist soil from the core sampler was taken out in a tray. The soil was scattered uniformly in the tray in thin layer. The tray was then placed in an electric oven at 105 °C for at least 24 hours without any disruption in power supply. The dry weight of the soil plus tray was taken. And the empty tray was weighed.

*Observations and Results* : The diameter and height of the core sampler are same as in § 4.5.

Weight of (soil tray+dry soil)$=W_3=2766{\cdot}51$ gm
Weight of empty tray$=W_4=975{\cdot}8$ gm
Weight of dry soil$=W_3-W_4=1790{\cdot}71$ gm

Volume of core (i.e., soil)$=\frac{\pi}{4}d^2h=1178{\cdot}0971$ cm$^3$

Thus $\rho_b=\frac{1790{\cdot}71}{1178{\cdot}0971}$ gm/cm$^3$$=1{\cdot}52$ gm/cm$^3$

*Alternatively* : $\rho_t$ and $P_w$ can be determined following § 4.5 and § 4.3.1, respectively as $\rho_t=1{\cdot}90$ gm/cm$^3$ and $P_w=25\%$

$$\therefore \quad \rho_b=\frac{\rho_t}{1+\frac{P_w}{100}}=\frac{1{\cdot}90}{1{\cdot}250}=1{\cdot}52 \text{ gm/cm}^3$$

## 4.7 DETERMINATION OF POROSITY AND VOLUMETRIC MOISTURE CONTENT OF SOIL

*Theory* : Porosity ($\theta_0$) is an index (relative) of pore space or pore volume present in a soil. Commonly it lies in between 0·3 to 0·6. It has nothing to do with pore size distribution.

$$\theta_0=\frac{\text{Volume of (Water+Air) present in soil mass}}{\text{Volume of (Solids+Water+Air) present in a soil mass}}$$

When all the pore space is filled up with water, the soil is denoted as saturated soil. Hence under 100% saturation the porosity and volume wetness are same.

$$\theta_0=1-\frac{\rho_b}{\rho_s} \tag{4.3}$$

where $\rho_s$ is the particle density of soil which differs from soil to soil but in absence of any reliable data an average of 2·65 gm/cm³ is generally taken for almost all purposes and $\rho_b$ is the dry bulk density of soil (vide § 4.6).

Using the above relation an approximate value of porosity can easily be obtained.

Volumetric moisture content or volume wetness or volume fraction of soil water are synonymous. The symbol $\theta$ is used here for this purpose.

$$\theta=\frac{\text{Volume of water present in a soil mass}}{\text{Volume of (Soil+Water+Air) present in a soil mass}}$$

Thus $\theta+\theta_a=\theta_0$ where $\theta_a$ is the air filled porosity. Again

$$\theta=\frac{\rho_b\times\text{Moisture content of soil in percentage}}{100}$$

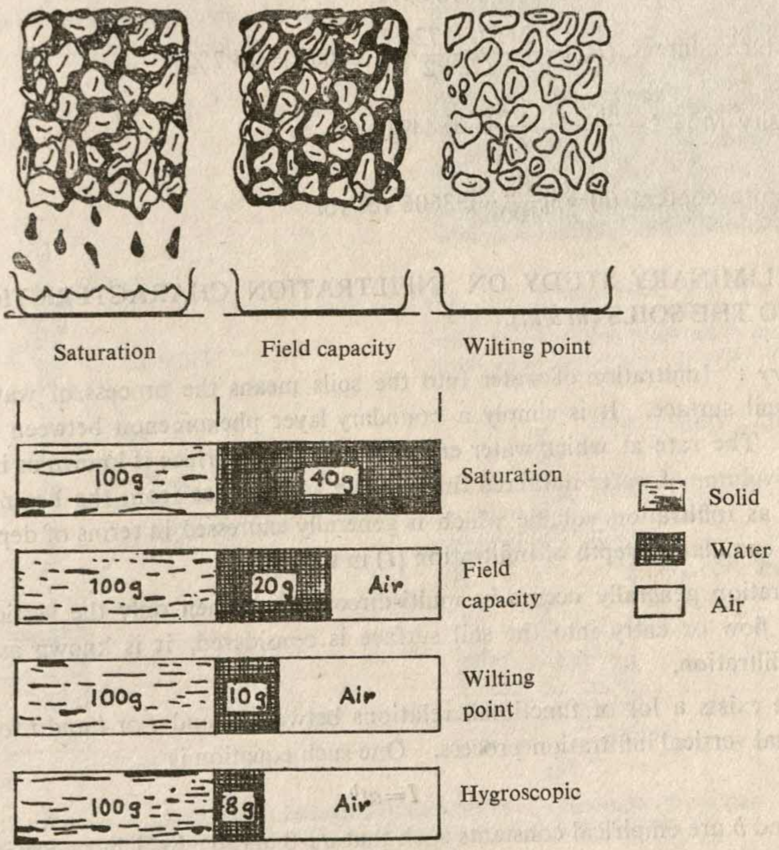


Fig. 4.14 A diagrammatic illustration of moisture content in the soil at different levels.

*Apparatus required* : Same as § 4.6

*Procedure* : The procedure described in § 4.5 and § 4.6 was followed.

*Observations and Results* :

Diameter ($d$) of the soil core = 10 cm
Length or height ($h$) of the soil core = 15 cm
Empty weight ($W_1$) of the soil core = 1800 gm
Weight of moist soil and core ($W_2$) = 3950 gm
Weight of moist soil and tray ($W_3$) = 2700 gm
Weight of empty tray ($W_4$) = 975·8 gm
Weight of moist soil $= W_2 - W_1$ = 2150 gm
Weight of dry soil $= W_3 - W_4$ = 1724·2 gm

$$\text{Volume of soil or soil core} = \frac{\pi}{4}d^2h = 1178{\cdot}0971 \text{ cm}^3$$

$$\therefore \text{ Dry bulk density } (\rho_b) = \frac{1724{\cdot}2}{1178{\cdot}0971} \text{ gm/cm}^3 = 1{\cdot}46 \text{ gm/cm}^3$$

$$\text{Moisture content } (P_w) = \frac{2150 - 1724{\cdot}2}{1724{\cdot}2} \times 100\% = 24{\cdot}7\%$$

$$\text{Porosity } (\theta_0) = 1 - \frac{\rho_b}{\rho_s} = 1 - \frac{1{\cdot}46}{2{\cdot}65} = 0{\cdot}4491$$

$$\text{Moisture content } (\theta) = \rho_b \frac{P_w}{100} = 0{\cdot}3606 \text{ vol/vol}$$

## 4.8 PRELIMINARY STUDY ON INFILTRATION CHARACTERISTICS OF WATER INTO THE SOILS (*in situ*).

*Theory* : Infiltration of water into the soils means the process of water entry into soils through soil surface. It is simply a boundary layer phenomenon between the soil and water interface. The rate at which water enters into the soil surface is known as infiltration rate ($i$). The total volume of water infiltered through the soil surface from the beginning of the event is known as infiltration volume which is generally expressed in terms of depth and commonly known as cumulative depth of infiltration ($I$) in time, $t$.

Infiltration generally occurs in multi-directions. When only the vertical component of the water flow or entry into the soil surface is considered, it is known as one-dimensional vertical infiltration.

There exists a lot of functional relations between $I$ and $t$ or $i$ and $t$ to describe the one-dimensional vertical infiltration process. One such equation is

$$I = at^b \tag{4.4}$$

where $a$ and $b$ are empirical constants such that $a > 0$ and $0 < b \leq 1$ but occasionally $b > 1$ also. This is known as Kostiakov or Lewis equation.

*Apparatus required* : A single cylinder infiltrometer, bucket, beaker, scale, watch or stopwatch, etc.

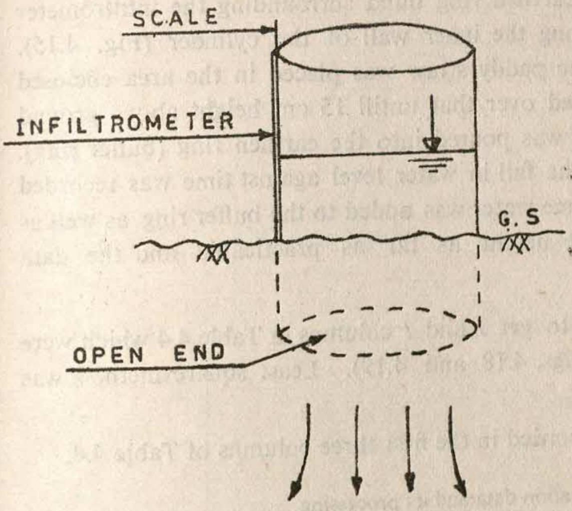


Fig. 4.15 A line sketch of a single ring cylinder infiltrometer installed in the field soil.

Fig. 4.16 Photographic view of a single ring cylinder infiltrometer installed in the field. A buffer ring has been prepared by earthen bunds to act as a double ring cylinder infiltrometer. Vide also Fig. 4.24.

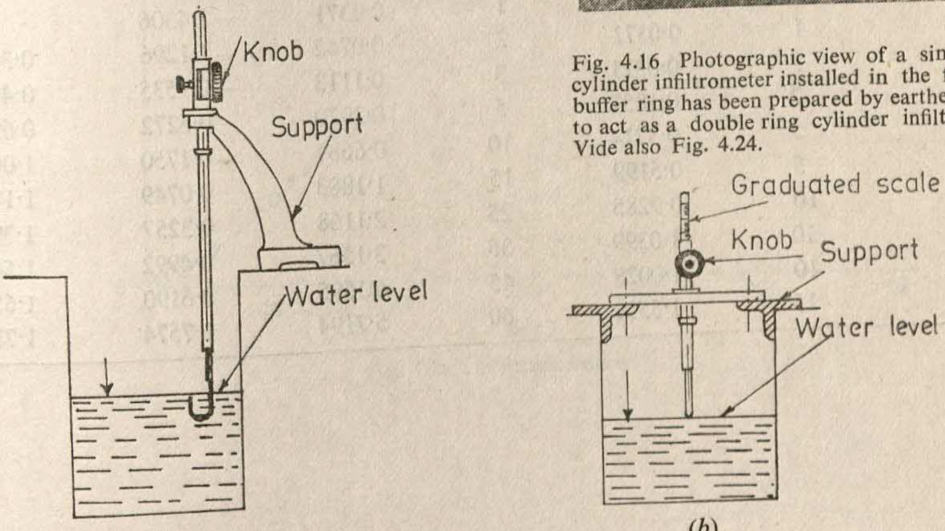


Fig. 4.17 For accurate reading of the depth of infiltration or evaporation from pan evaporimeter (a) hook gauge or (b) point gauge may suitably be used.

*Procedure* : The infiltrometer (Fig. 4.15) was installed on a soil site (*in situ*) of our choice by hammering slowly from the top using a wooden plank and a hammer up to a depth of 15 cm or so. As shown in Fig. 4.16 an earthen ring bund surrounding the infiltrometer was made. A scale was fitted vertically along the inner wall of the cylinder (Fig. 4.15). To avoid splash erosion and surface crust some paddy straw was placed in the area enclosed by the cylinder after which water was poured over that untill 15 cm height above ground surface was reached. Simultaneously, water was poured into the earthen ring (buffer ring). The paddy straw was quickly taken out. The fall in water level against time was recorded in the format shown in Table 4.4. Time to time water was added to the buffer ring as well as inside the cylinder to maintain a constant height as far as practicable and the data (inner cylinder) were recorded appropriately.

The data thus obtained were processed to get *I* and *t* columns in Table 4.4 which were plotted in plain and log-log graph papers (Figs. 4.18 and 4.19). Least square method was followed to fit the data set in (Eq 4.4).

*Observations* : Experimental data are recorded in the first three columns of Table 4.4.

Table 4.4 Observed infiltration data and its processing

| *Time by watch* | *Time interval* min | *Water depth infiltered during time interval* cm | *t* min | *I* cm | *log I* ($y$) | *log t* ($x$) |
|---|---|---|---|---|---|---|
| 8–47 am | 0 | 0 | 0 | 0 | — | — |
| 8–48 | 1 | 0·0371 | 1 | 0·0371 | −1·4306 | 0 |
| 8–49 | 1 | 0·0371 | 2 | 0·0742 | −1·1296 | 0·3010 |
| 8–50 | 1 | 0·0371 | 3 | 0·1113 | −0·9535 | 0·4771 |
| 8–52 | 2 | 0·1857 | 5 | 0·2970 | −0·5272 | 0·6990 |
| 8–57 | 5 | 0·3714 | 10 | 0·6684 | −0·1750 | 1·0000 |
| 9–02 | 5 | 0·5199 | 15 | 1·1883 | 0·0749 | 1·1761 |
| 9–12 | 10 | 0·9285 | 25 | 2·1168 | 0·3257 | 1·3979 |
| 9–22 | 10 | 1·0399 | 35 | 3·1567 | 0·4992 | 1·5441 |
| 9–32 | 10 | 1·0028 | 45 | 4·1595 | 0·6190 | 1·6532 |
| 9–47 | 15 | 1·5599 | 60 | 5·7194 | 0·7574 | 1·7782 |

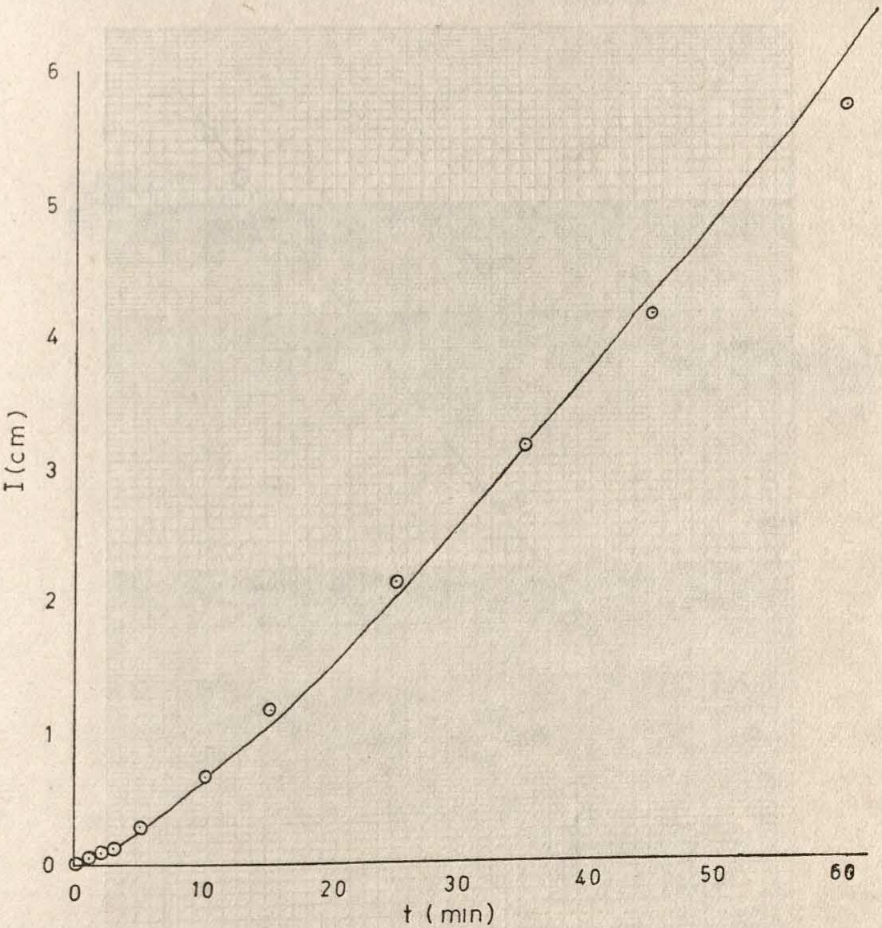


Fig. 4.18 Infiltration curve.

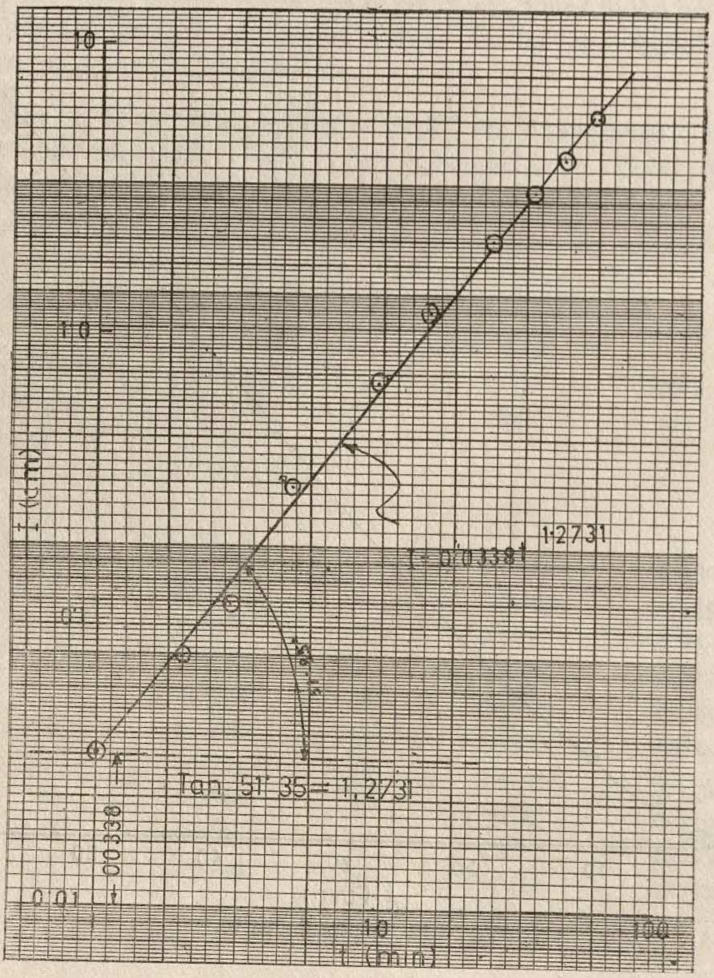


Fig. 4.19 The data of Fig. 4.18 are plotted on a log-log scale, i.e., infiltration curve on a log-log graph. Open circles are observed data points. Solid line is drawn as per equation.

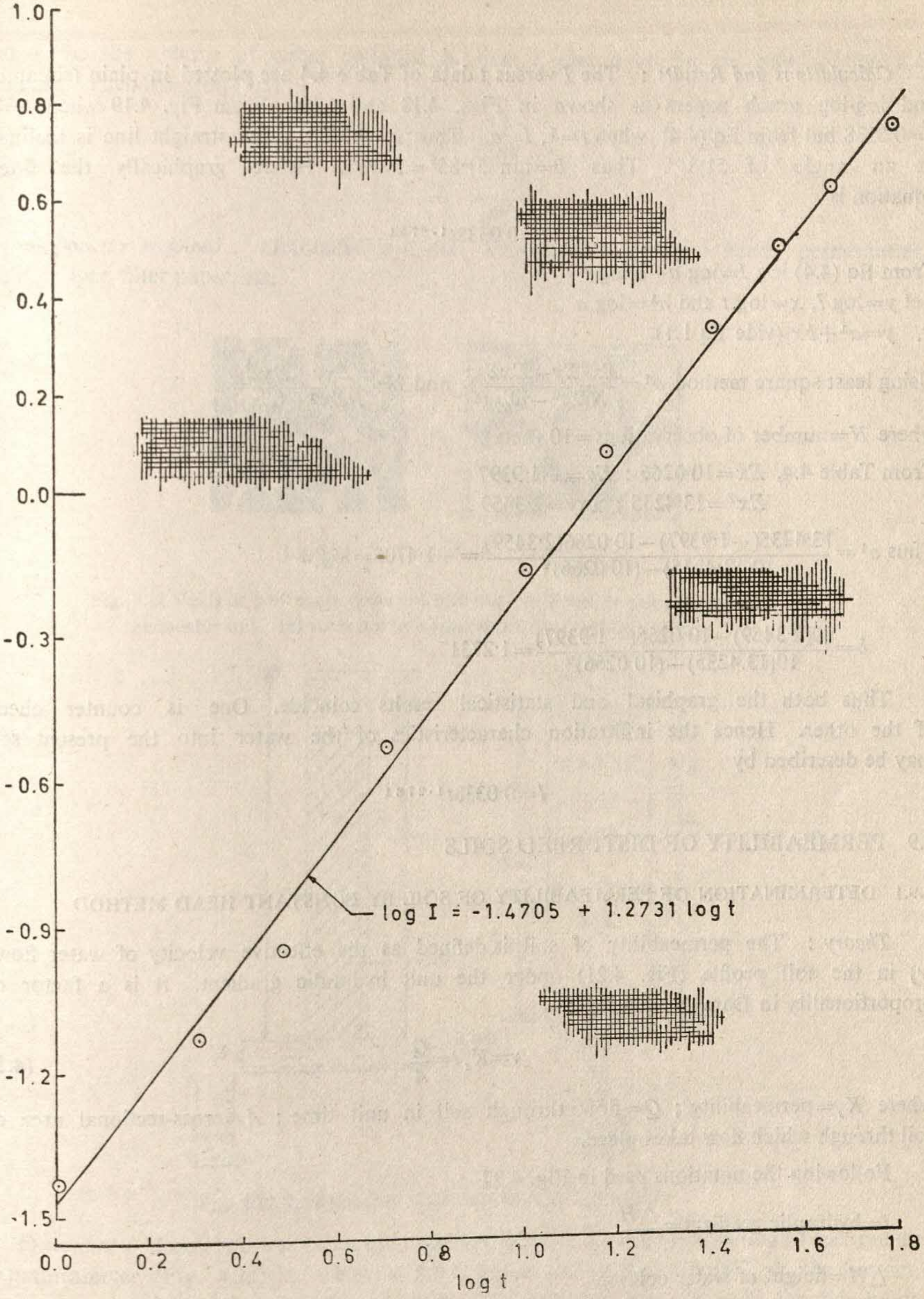


Fig. 4.20 The plot of log *I* against log *t* in squared graph paper as an alternative of the plot of Fig. 4.19. This may be tried in case log-log graph papers are not available.

*Calculations and Results* : The $I$ versus $t$ data of Table 4.4 are plotted in plain (squared) and log-log graph papers as shown in Figs. 4.18 and 4.19. From Fig. 4.19 when $t=1$, $I=0{\cdot}0338$ but from Eq (4.4) when $t=1$, $I=a$. Thus $a=0{\cdot}0338$. The straight line is inclined at an angle of 51·85°. Thus $b=\tan 51{\cdot}85°=1{\cdot}2731$. Hence graphically the fitted equation is

$$I=0{\cdot}0338t^{1{\cdot}2731}$$

From Eq (4.4) $\log I=\log a+b\log t$

Let $y=\log I$, $x=\log t$ and $a^1=\log a$

$\therefore\ y=a^1+bx$ (vide Eq 1.1).

Using least square method $a^1=\dfrac{\Sigma x^2\Sigma y-\Sigma x\Sigma xy}{N\Sigma x^2-(\Sigma x)^2}$ and $b=\dfrac{N\Sigma xy-\Sigma x\Sigma y}{N\Sigma x^2-(\Sigma x)^2}$

where $N$=number of observations=10 (here)

From Table 4.4, $\Sigma x=10{\cdot}0266$ ; $\Sigma y=-1{\cdot}9397$

$\Sigma x^2=13{\cdot}4235$ ; $\Sigma xy=2{\cdot}3459$

$$\text{Thus } a^1=\frac{13{\cdot}4235(-1{\cdot}9397)-10{\cdot}0266(2{\cdot}3459)}{10(13{\cdot}4235)-(10{\cdot}0266)^2}=-1{\cdot}4705=\log a$$

$$\therefore\ a=0{\cdot}0338$$

$$b=\frac{10(2{\cdot}3459)-10{\cdot}0266(-1{\cdot}9397)}{10(13.4235)-(10{\cdot}0266)^2}=1{\cdot}2731$$

Thus both the graphical and statistical results coincide. One is counter check of the other. Hence the infiltration characteristics of the water into the present soil may be described by

$$I=0{\cdot}0338t^{1{\cdot}2731}$$

## 4.9 PERMEABILITY OF DISTURBED SOILS

### 4.9.1 DETERMINATION OF PERMEABILITY OF SOIL BY CONSTANT HEAD METHOD

*Theory* : The permeability of soil is defined as the effective velocity of water flows ($v$) in the soil profile (Fig. 4.21) under the unit hydraulic gradient. It is a factor of proportionality in Darcy's equation :

$$v=K_s i=\frac{Q}{A} \tag{4.5}$$

where $K_s$=permeability ; $Q$=flow through soil in unit time ; $A$=cross-sectional area of soil through which flow takes place.

Following the notations used in Fig. 4.22

$i$=hydraulic gradient$=\dfrac{\triangle H}{L}$

$\triangle H$=height of water column

$L$=length of soil column

Let $V$ be the volume of water collected in time $t$ and $d$ be the diameter of the soil column. Then from Eq (4.5)

$$K_s \frac{\triangle H}{L} = \frac{V/t}{\frac{\pi}{4}d^2}$$

$$\text{i.e., } K_s = \frac{VL}{\frac{\pi}{4}d^2 \triangle Ht} \tag{4.6}$$

*Apparatus required* : Graduated cylinder, stopwatch, constant head permeameter, scale, caliper, filter paper, etc.

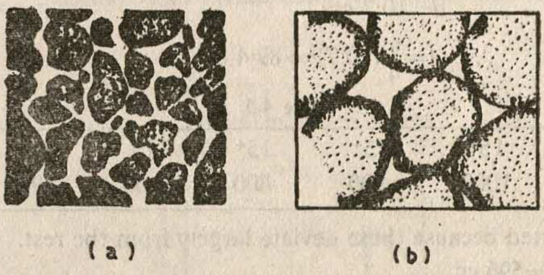


Fig. 4.21 Voids or pore space through which water will find its passageway in a permeable soil. (a) voids not in a same plane, (b) voids in a plane.

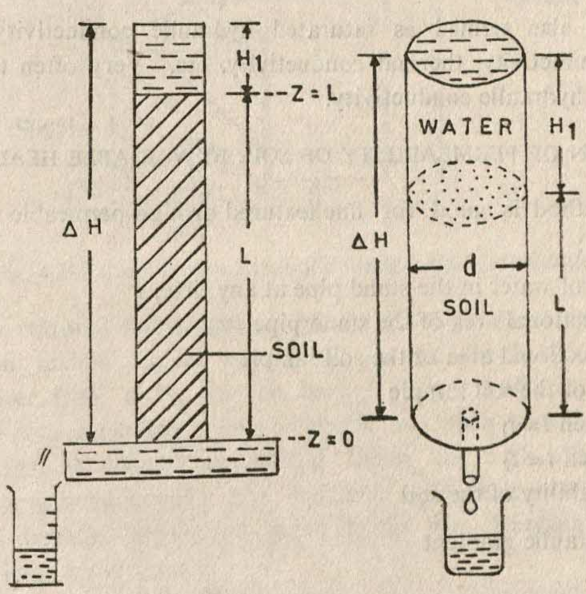


Fig. 4.22 Line sketches of constant head permeameters.

*Procedure* : Local soil was taken after passing through 60 mesh size sieve and was put in the permeameter (Fig. 4.22) in which a filter paper was placed apriori at the bottom. Water was poured on the permeameter with soil and was kept as such for few hours (in some cases few days may be required) for saturation. After satisfactory saturation water level in the permeameter was brought back (by adding water) to the desired level which was maintained by adding water manually from time to time or by using an automatic device. The water passed through the soil column was collected in a beaker placed below. The time was noted after the first drop of water was collected in the beaker. After 15 min the beaker was taken out and the water collected was measured using a measuring cylinder. The process was repeated for 6 times.

*Observations and Results* : $\triangle H = 16{\cdot}2$ cm

$L = 9{\cdot}4$ cm

$d = 10{\cdot}7$ cm

$\therefore \quad A = \frac{\pi}{4}(10{\cdot}7)^2 = 89{\cdot}4$ cc

Table 4.5

| $t$, min | $15^{+}$ | $15^{+}$ | $15^{+}$ | 15 | 15 | 15 |
|---|---|---|---|---|---|---|
| $V$, cc | 1000 | 900 | 800 | 600 | 591 | 597 |

+Rejected because these deviate largely from the rest.

$\therefore$ Average $V = 596$ cc

$$K_s = \frac{VL}{A \triangle H t} = \frac{596\,(9{\cdot}4)}{89{\cdot}4(16{\cdot}2)15} \text{ cm/min} = 15{\cdot}5 \text{ cm/hour}$$

*Remark* : $K_s$ is also termed as saturated hydraulic conductivity to maintain parity with the electrical conductivity, thermal conductivity, etc. Very often the symbol $K$ is used to denote unsaturated hydraulic conductivity.

### 4.9.2. DETERMINATION OF PERMEABILITY OF SOIL BY VARIABLE HEAD PERMEAMETER

*Theory* : This method is good for fine textured or high permeable soils. Following the notations of Fig. 4.23 :

$H$=height of water in the stand pipe at any time, $t$
$a$=cross-sectional area of the stand pipe
$A$=cross-sectional area of the soil sample
$L$=length of the soil sample
$H=H_1$ when $t=t_1$
$H=H_2$ when $t=t_2$
$K$=permeability of the soil
$i=\frac{H}{L}$=hydraulic gradient

Let $u$=velocity of flow in stand pipe$=-\frac{dH}{dt}$ (negative because of falling head)

$u_1$=velocity of flow through soil column$=Ki$ (from Darcy's law)

$Q$=discharge through stand pipe (obviously this is also the discharge through soil column)$=au=Au_1$ (from equation of continuity)

$$\therefore \quad au = KiA = K\frac{H}{L}A$$

Or $-a\frac{dH}{dt} = K\frac{H}{L}A$

Integrating between $H_1$ to $H_2$ and $t_1$ to $t_2$

$$K = \frac{aL}{A(t_2 - t_1)} \ln \frac{H_1}{H_2} \tag{4.7}$$

All the variables in the right-hand side can be measured and $K$ can be determined accordingly.

*Apparatus required* : Variable head permeameter with glass stand pipe, stopwatch, funnel and beaker.

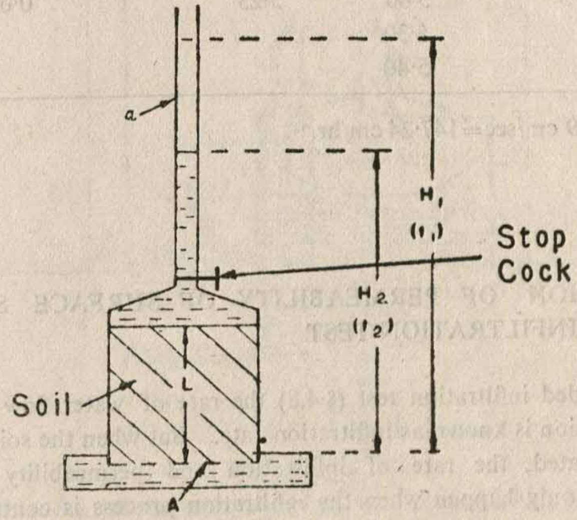


Fig. 4.23 Cross-sectional view of a variable head permeameter.

*Procedure* : Fine textured soil sample was placed in the permeameter (Fig. 4.23). Stopcock was kept open and a funnel was fitted in the stand pipe. Arrangement was made to supply water from a tap to the funnel continuously for about an hour or till the soil sample was saturated. The stopcock was then closed and the stand pipe was kept water-filled. A beaker was placed below the soil sample. The stopcock was opened and $H_1$, $t_1$ were noted. The stopcock was then closed and $H_2$, $t_2$ were recorded. This was repeated thrice for each $H_1$ and $H_2$. Readings were also recorded by varying $H_1$ for at least three times.

The $a$, $A$ and $L$ were measured suitably.

*Observations* and *Results* :

Cross-sectional area of stand pipe, $a = 1{\cdot}111$ cm$^2$

Cross-sectional area of soil column, $A = 36{\cdot}32$ cm$^2$

Length of soil column, $L = 9{\cdot}00$ cm.

Table 4.6

| $H_1$ cm | $H_2$ cm | $(t_2-t_1)$ sec | Average | $K=\frac{0\cdot6340}{(t_2-t_1)}\log_{10}\frac{H_1}{H_2}$ cm/sec |
|---|---|---|---|---|
| 58·6 | 23·5 | 6·00 | 5·85 | 0·0430 |
| | | 5·75 | | |
| | | 5·80 | | |
| 54·1 | 23·5 | 5·80 | 5·70 | 0·0403 |
| | | 5·60 | | |
| | | 5·70 | | |
| 49·6 | 23·5 | 5·00 | 5·23 | 0·0393 |
| | | 5·30 | | |
| | | 5·40 | | |

Average $K=0\cdot0409$ cm/sec$=147\cdot24$ cm/hr.

## 4.10 DETERMINATION OF PERMEABILITY OF SURFACE SOIL (*in situ*) BY PROLONGED INFILTRATION TEST

*Theory* : In ponded infiltration test (§ 4.8) the rate of water flow into the soil under unsaturated soil condition is known as infiltration rate. But when the soil layer at the site of infiltration gets saturated, the rate of infiltration and permeability becomes identical. Theoretically it may only happen when the infiltration process is continued for an infinite time by which it is assumed that the top soil becomes saturated. Afterwards the water makes its entry into the soil at a constant rate which is also termed as final infiltration rate. This final infiltration rate is akin to the permeability of the soil.

In actual practice the time taken to saturate the top surface soil may be a few hours to few months depending on soil and other factors related to the soil profile up to semi-infinite depth. A minimum of 72 hours is assumed to be required to saturate the soil layer in contact with infiltrating water, if the infiltration process is allowed to continue without any disruption. After this period the rate of infiltration may be measured and taken as the permeability.

This method is quite good for irrigation and drainage practices.

*Experimental set up* : A buffer ring cylinder infiltrometer, two float valves with accessories, plastic or rubber pipes, two sets of water reservoirs, scale, watch, etc. (Fig. 4.24).

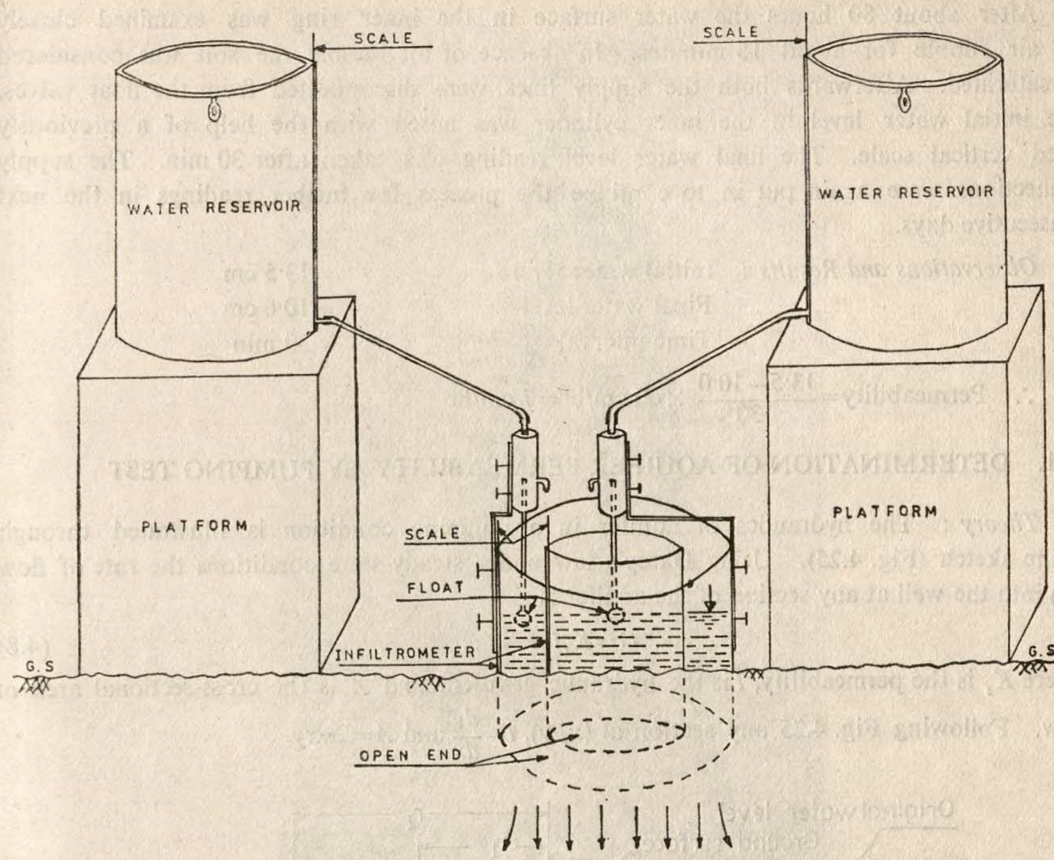


Fig 4.24

Sketch of a double ring cylinder infiltrometer fitted with a constant head (water) maintaining device and water supply arrangements for a prolonged infiltration test (Vide Fig. 4.16).

*Procedure* : A buffered cylinder infiltrometer was pushed to a depth of 15 cm into the soil (*in situ*). The diameters of the outer and inner rings were 53 cm and 33 cm, respectively. The height of the infiltrometer was 45 cm of which 30 cm was above the ground. A 10 cm gap in the annular space was available.

To supply water continuously into both the rings for a long time two drums (Fig. 4.24) one eaeh for inner and outer cylinders were used as water reservoirs. One outlet pipe from each of the drums was connected with the supply system of the float valve fitted in the rings. Both the drums were filled with water. Few buckets of water were poured into the annular and inner rings simultaneously till the water levels in both rings reached to 13·5 cm from ground surface. The supply lines from the drums to the float valves were then kept open. With this arrangement water was automatically supplied from the drums to the rings to maintain a constant water level of 13·5 cm. The water levels in the drums (supply reservoirs) were checked from time to time and the drums were refilled according to the need.

After about 80 hours the water surface in the inner ring was examined closely for air bubble for about 15 minutes. In absence of air bubble the soil was considered as saturated. Afterwards both the supply lines were disconnected from the float valves. The initial water level in the inner cylinder was noted with the help of a previously fitted vertical scale. The final water level reading was taken after 30 min. The supply connections were again put in to continue the process for further readings in the next consecutive days.

*Observations and Results* : Initial water level $=13{\cdot}5$ cm
Final water level $=10{\cdot}0$ cm
Time interval $=30$ min

$$\therefore \quad \text{Permeability}=\frac{13{\cdot}5-10{\cdot}0}{30}\times 60 \text{ cm/hr}=7 \text{ cm/hr}$$

## 4.11. DETERMINATION OF AQUIFER PERMEABILITY BY PUMPING TEST

*Theory* : The hydraulics of aquifer in a pumping condition is illustrated through a line sketch (Fig. 4.25). Using Darcy's law under steady-state conditions the rate of flow ($Q$) into the well at any section of the aquifer is

$$Q=K_s i A \tag{4.8}$$

where $K_s$ is the permeability, $i$ is the hydraulic gradient and $A$ is the cross-sectional area of flow. Following Fig. 4.25 any section at $(x, y)$, $i=\frac{dy}{dx}$ and $A=2\pi xy$

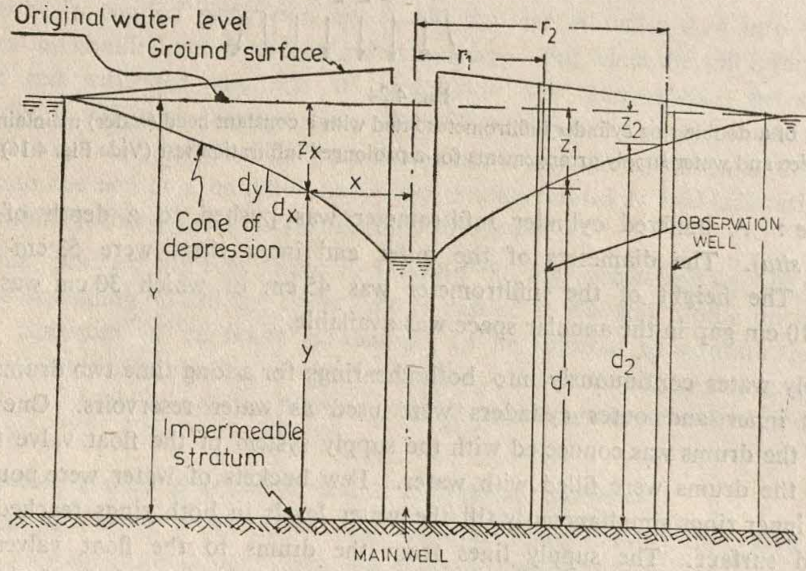


Fig. 4.25 Determination of permeability of aquifer soil through pumping test using piezometers to measure fall in water levels. The observation wells in the left-hand side at $r_1$ and $r_2$ are not shown here.

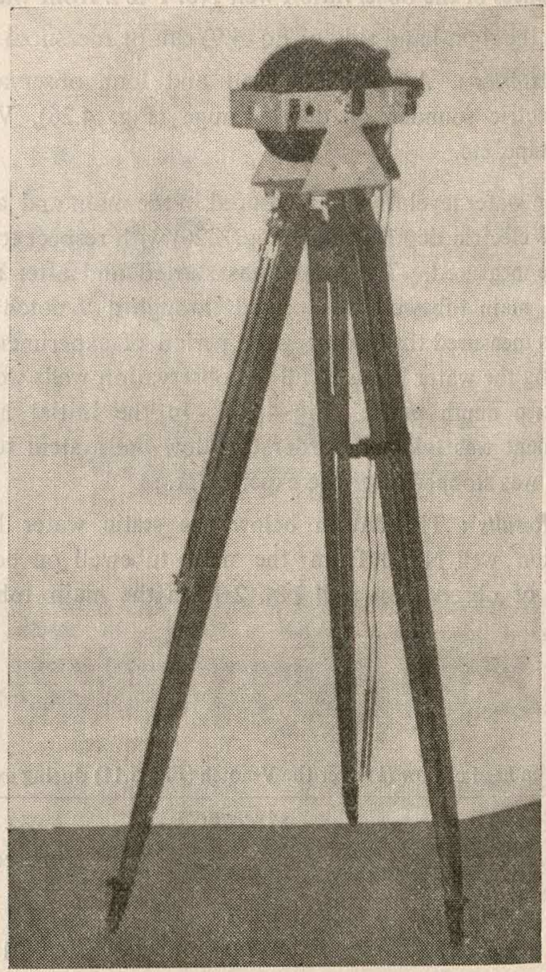


Fig. 4.26 An electric sounder or depth gauge to record water levels in piezometers (observation wells) or tubewells.

Hence $Q = K_s \dfrac{dy}{dx}(2\pi xy)$

Or, $Q \displaystyle\int_{r_1}^{r_2} \frac{dx}{x} = 2K_s\pi \int_{d_1}^{d_2} y\,dy$

$$\text{i.e., } K_s = \frac{Q \ln \dfrac{r_2}{r_1}}{\pi(d_2^2 - d_1^2)} \qquad (4.9)$$

where $K_s$ = permeability of the aquifer

$Q$ = discharge of the tubewell

$d_1$, $d_2$ = heights of water level in observation well No. 1 & 2 (Fig. 4·25)

$r_1$, $r_2$=distances of the observation well No. 1 & 2 from the centre of the tubewell

The parameters in the right-hand side of Eq (4.9) can be measured to find out $K_s$.

*Experimental accessories* : A main tubewell and four observation wells in an area (Fig. 4.25), pump, electric sounder or depth gauge (Fig. 4.26), V-notch and accessories (Fig. 5.11), measuring tape, etc.

*Procedure* : Static water level ($l$) was measured in the main and all the four observation wells with the help of electric depth gauge (Fig. 4.26) with respect to the ground level. The distances $r_1$ and $r_2$ were measured. The pump was started and after about half an hour the water yield from the main tubewell was passed through a V-notch (§ 5.3). The head over V-notch (Fig. 5.11) was measured thrice during the period of experimentation. Corresponding to each V-notch reading the water levels in all the observation wells were noted simultaneously with the help of electric depth gauge (Fig. 4.26). In the initial half an hour period of pumping no measurement was taken in order to allow the system to reach to a steady-state condition. The pump was stopped after the experiment.

*Observations and Results* : The datum below the static water level is at 100 m (say). Distance of observation well No. 1 from the main tubewell on both left and right sides ($r_1$)=75 m. Distance of observation well No. 2 from the main tubewell on both left and right sides ($r_2$)=150 m.

Table 4.7 Data on head of flow ($h$) over the V-notch (Fig. 5.11) during experimentation.

| $h$ cm | *Average* $h$ cm | $Q^+$ m$^3$/sec |
|---|---|---|
| 17·10 | 17·05 | 0·017 |
| 17·05 | | |
| 17·00 | | |

+Using Eq. (5.1) and assuming Cd=0·6, $g$=981 cm/sec$^2$ and $\theta$=90°.

Table 4.8 Data on $z_1$ and $d_1$ as per Fig. 4.25.

| | *LHS* | | | *RHS* | | | |
|---|---|---|---|---|---|---|---|
| $z_1+l$ m | $l$ m | $z_1$ m | $z_1+l$ m | $l$ m | $z_1$ m | *Average* $z_1$ m | $d_1$ (100−$z_1$) m |
| 8·90 | 3·0 | 5·90 | 9·06 | 3·1 | 5·96 | 5·93 | 94·07 |
| 8·88 | | 5·88 | 9·08 | | 5·98 | | |
| 8·86 | | 5·86 | 9·10 | | 6·00 | | |

Table 4.9 Data on $z_2$ and $d_2$ as per Fig. 4.25

| | *LHS* | | | *RHS* | | *Average* | $d_2$ |
|---|---|---|---|---|---|---|---|
| $z_2+l$ | $l$ | $z_2$ | $z_2+l$ | $l$ | $z_2$ | $z_2$ | $(100-z_2)$ |
| m | m | m | m | m | m | m | m |
| 5·80 | | 4·30 | 5·84 | | 4·44 | | |
| 5·82 | 1·5 | 4·32 | 5·82 | 1·4 | 4·42 | 4·37 | 95·63 |
| 5·84 | | 4·34 | 5·80 | | 4·40 | | |

In Tables 4.8 & 4.9 the terms LHS and RHS are used to denote left-hand side and right-hand side, respectively, with respect to the main tubewell and the symbol $l$ is used to mean static water level with reference to the ground surface.

Thus

$$K_s = \frac{Q \log_e \frac{r_2}{r_1}}{\pi(d_2^2 - d_1^2)} = \frac{0{\cdot}017 \log_e \left(\frac{150}{75}\right)}{\pi(95{\cdot}63^2 - 94{\cdot}07^2)}$$

$$= 1{\cdot}2675 \times 10^{-5} \text{ m/sec.}$$

$$= 4{\cdot}56 \text{ cm/hr.}$$

*Remark* : In absence of an electric depth gauge (Fig. 4·26) a thread tied at one end with a suitable size and shape of a piece of heavy wood may be slowly dropped into the piezometer until it touches (realized by feeling) the water level. This may then be taken out and measured from the top mark to the water front mark on the wood piece.

# 5

# Water Flow Measurement

## 5.1 DISCHARGE BY WEIRS

### 5.1.1 DETERMINATION OF DISCHARGE BY A TRIANGULAR WEIR OR V-NOTCH

*Theory* : The discharge($Q$) through a V-notch can be estimated as

$$Q=\frac{8}{15}C_a\sqrt{2g}\,h^{5/2}\tan\left(\frac{\theta}{2}\right) \tag{5.1}$$

where $C_a$ is the coefficient of discharge, $h$ is the head (as shown in Fig. 5.3) of the water over the crest and $\theta$ is the angle of the triangular weir or V-notch.

The units may be chosen consistently.

*Experimental Accessories* : A triangular weir or V-notch (Fig. 5.1) fitted suitably as shown in Fig. 5.2 or 5.3 ; water supply, scale, angle-measuring device, etc.

*Procedure* : A piece of white paper was placed (when there was no water flow) tightly over the notch and pencil lines were drawn along the edges of the notch. The angle thus obtained was then measured. The flow was then passed. The head($h$) of the flow from the zero point (Fig. 5.1) or crest of the notch was measured at a distance of 50 cm away (horizontally) from the notch.

*Observations and Results* : $\theta=90°$ ; $h=10{\cdot}5$ cm ; $C_a=0{\cdot}6$ (assumed or obtained from the calibration test)

$$\therefore \quad Q=\frac{8}{15}(0{\cdot}6)\sqrt{2(981)}(10{\cdot}5)^{5/2}\tan 45°=5063{\cdot}70 \text{ cm}^3/\text{sec}$$

*Precaution* : The position of stilling well as shown in Fig. 5.2 for measuring $h$ shall be at least $4h$ away from the weir or notch.

### 5.1.2 MEASUREMENT OF DISCHARGE BY A RECTANGULAR WEIR

*Theory* : The length($B$) of a weir may be equal to or greater or lesser than the width($L$) of the upstream channel (Fig. 5.4). The weir is said to be with end contraction if $B<L$.

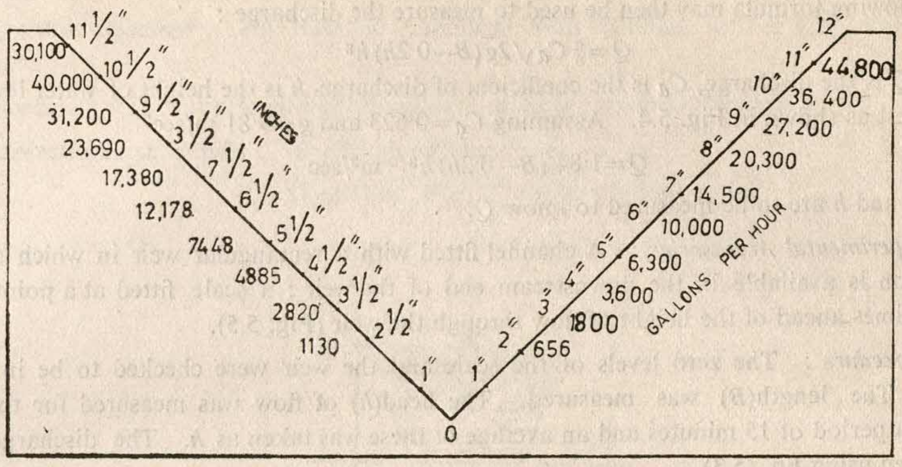


Fig. 5.1. A calibrated triangular weir or 90° V-notch made of steel sheet.

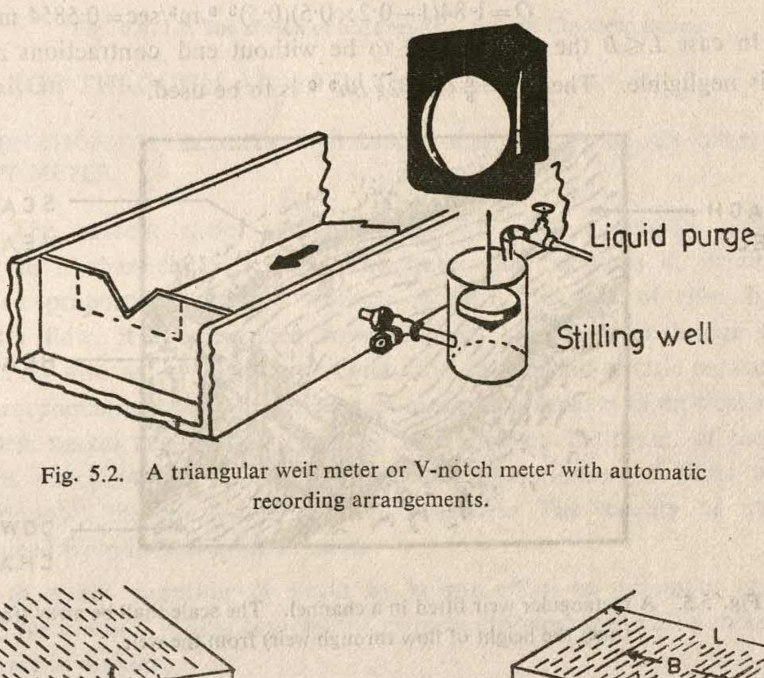


Fig. 5.2. A triangular weir meter or V-notch meter with automatic recording arrangements.

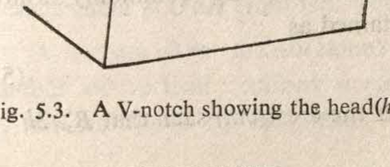


Fig. 5.3. A V-notch showing the head($h$) of flow.

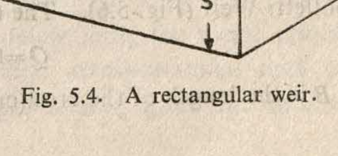


Fig. 5.4. A rectangular weir.

The following formula may then be used to measure the discharge :

$$Q=\tfrac{2}{3}\, C_a\sqrt{2g}\,(B-0{\cdot}2h)\, h^{3/2} \tag{5.2}$$

where $Q$ is the discharge, $C_a$ is the coefficient of discharge, $h$ is the height of water level above weir crest as shown in Fig. 5.4. Assuming $C_a=0{\cdot}623$ and $g=9{\cdot}81$ m/sec$^2$

$$Q=1{\cdot}84\ (B-0{\cdot}2h)\, h^{3/2}\ \text{m}^3/\text{sec} \tag{5·3}$$

Only $B$ and $h$ are to be measured to know $Q$.

*Experimental Accessories* : A channel fitted with a rectangular weir in which a free-fall condition is available in the downstream end of the weir ; a scale fitted at a point which is 4 to 6 times ahead of the height of flow through the weir (Fig. 5.5).

*Procedure* : The zero levels of the scale and the weir were checked to be in the same plane. The length($B$) was measured. The head($h$) of flow was measured for three times within a period of 15 minutes and an average of these was taken as $h$. The discharge($Q$) was estimated using Eq. (5.3).

*Observations and Results* : $B=1$ m and $h=0{\cdot}5$ m

$$Q=1{\cdot}84(1-0{\cdot}2\times0{\cdot}5)(0{\cdot}5)^{3/2}\ \text{m}^3/\text{sec}=0{\cdot}5854\ \text{m}^3/\text{sec}$$

*Note* : In case $L\leqslant B$ the weir is said to be without end contractions and the velocity of approach is negligible. Then $Q=\frac{2}{3}\, C_a\sqrt{2g}\, Bh^{3/2}$ is to be used.

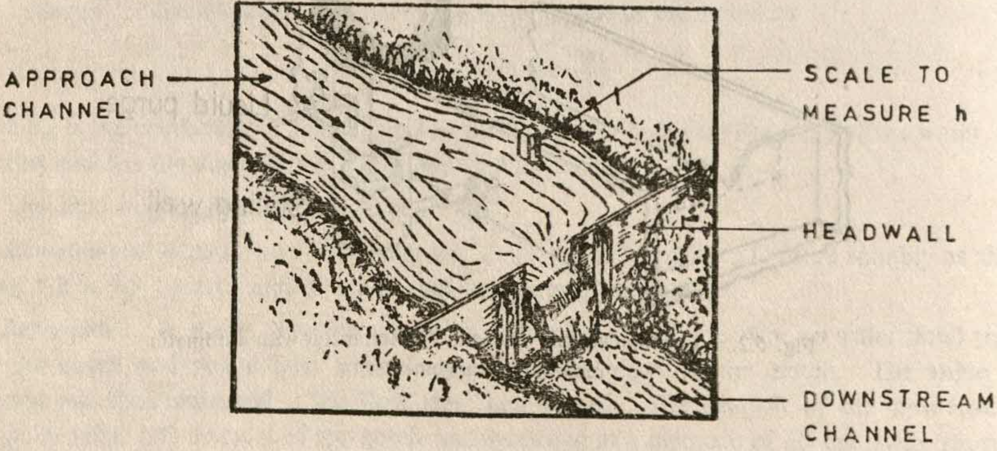


Fig. 5.5. A rectangular weir fitted in a channel. The scale shall be away (four times the height of flow through weir) from the weir.

### 5.1.3 MEASUREMENT OF DISCHARGE BY A TRAPEZOIDAL WEIR

*Theory* : In case the sides of the weir have a slope of 1 horizontal to 4 vertical, it does not require corrections for end contractions. Such weirs are commonly known as Cipolletti Weir (Fig. 5.6). The discharge($Q$) may be obtained as

$$Q=0{\cdot}0186Bh^{3/2}\ \text{litres/sec} \tag{5.4}$$

where $B$ is the length of the crest(cm) and $h$ is the head over the crest(cm) such that $B\geqslant3h$

*Apparatus Required* : An installed Cipolletti Weir (similar to Fig 5.2), scale, water supply, etc.

*Procedure* : The crest length and head of flow were measured (Fig 5.6)

*Observations and Results* : $B=20$ cm and $h=5$ cm

$$\therefore \quad Q=0{\cdot}0186(20)(5)^{3/2} \text{ lit/sec} = 4{\cdot}1591 \text{ lit/sec}$$

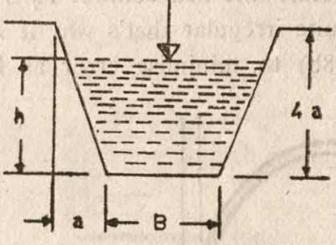


Fig. 5.6. A line sketch of a trapezoidal weir of Cipolletti design.

## 5.2 DISCHARGE THROUGH AN OPEN CHANNEL

### 5.2.1 DETERMINATION OF VELOCITY AND DISCHARGE THROUGH AN OPEN CHANNEL BY CURRENT METER

*Theory* : The current meter as shown in Fig. 5.7 is usually submerged under flowing water in a channel, river, etc. The water flow actuates it, driving the conical cups at a speed proportional to the velocity of flow. In case of river like streams or any deep water flow, it is suspended from a boat, cable car or bridge (Fig. 5.9) by a cable which serves also as an electricity conductor to transmit electric contacts made by the cup wheel to earphones carrying the message of makes and breakes of an electric circuit. The number of such makes and breaks is directly depended on the r.p.m. of the shaft. A dry cell of 4 volts energises the circuit. By counting the number of beats against a time noted by a stopwatch the revolutions can be calculated. The velocity of water flow may then be determined from the calibration curve.

In order to avoid counting of beats by human effort an automatic recorder may be connected with the circuit. Some equipments provide chronograph which records number of beats against time in a chart.

The velocity variation with depth in channels or streams is parabolic (Fig. 5.8a) and hence average velocities measured at $0{\cdot}2H$ and $0{\cdot}8H$ (where $H$ is the depth of flow) may approximate the mean velocity in a vertical section. For shallow flow a single measurement at $0{\cdot}6H$ from free water surface may also serve the purpose.

A stream flow measurement is generally made by determining the mean velocity in a number of vertical sections across the stream (Fig. 5.8b). Cross-sectional area of each section multiplied by the mean velocity measured in that section gives the discharge of that section. The total discharge is obtained by adding all the discharges of all the sub-sections.

*Experimental Accessories* : A flowing channel, current meter with all accessories, stopwatch, tape, pegs, threads, a depth probe, etc.

*Procedure* : The experiment was carried out in an irregular-shaped natural channel having 3 m width and 1·5 m maximum depth of flow at our point of consideration. The depth probe rod was used to measure the depths of flow at various points in such a fashion that after plotting against a scale the bed contour *PqrS* (Fig. 5.8b) was obtained. Since the whole cross-section was quite irregular that's why it was divided into sub-sections as *PQq*, *QqrR* and *RrS* (Fig. 5.8b) to minimise error as far as possible. Since the flows

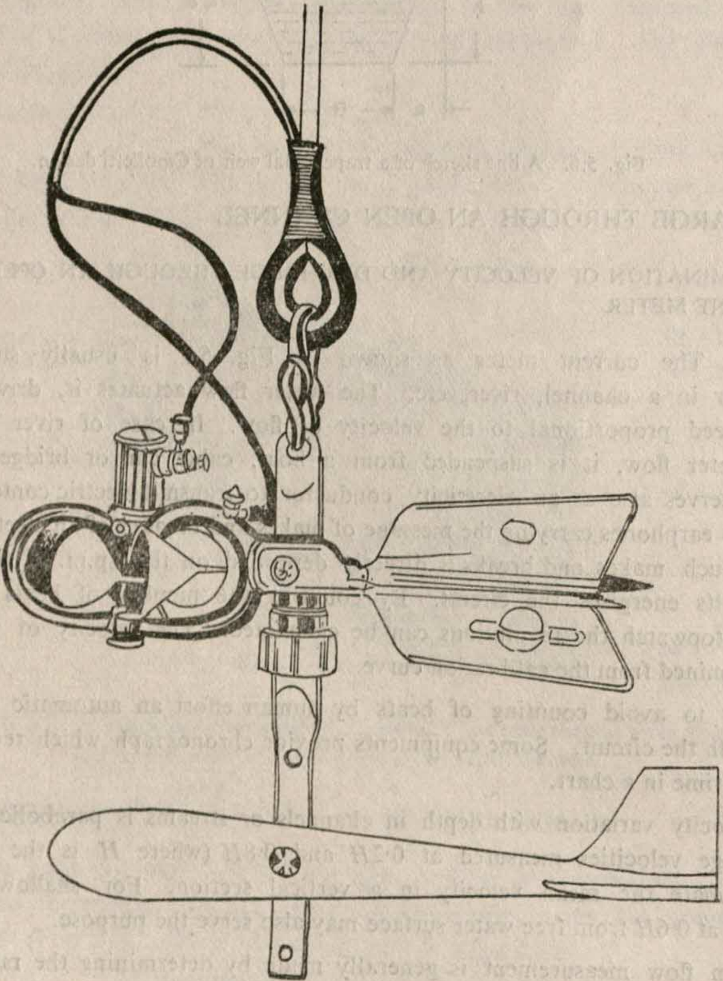


Fig. 5.7. Cup type current meter.

in sub-sections *PQq* and *RrS* are shallow that's why only at 0·6*H* (i.e., 0·42 m below from the free water surface) the current meter was placed to record velocity. For sub-section *QqrR* the metre was placed at 0·2*H* and 0·8*H* depth from the free water surface. The headphone was placed in the ears after making the electric circuit complete and the number of beats against a time by stopwatch was counted. The revolutions thus obtained were recorded in Table 5.1. From the Fig. 5.8b the area of each sub-section was determined by counting the number of small squares (if plotted in squared paper) and converted suitably following the scale used in the figure. Thus a set of velocities and areas of water flow data at the chosen station on the channel were obtained. The calculations were made following the guidelines in the theory.

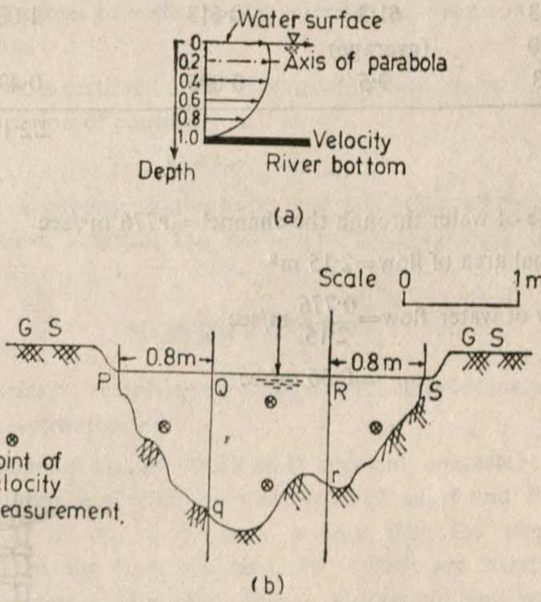


Fig. 5.8. (a) Velocity variation with depth in a river or channel, (b) Cross-section and other details of the experimental channel probed with a current metre.

*Observations* :

Table 5.1 Cup revolution, time and other data obtained from an experimental observation with current meter

| *Sub-section* | *Width* (m) | *Observation depth* (m) | *Revolutions number* | *Time* (sec) |
|---|---|---|---|---|
| *PQ* | 0·8 | 0·42 | 10 | 60 |
| *QR* | 1·0 | 0·24 | 40 | 72 |
| | | 0·86 | 20 | 60 |
| *RS* | 0·8 | 0·42 | 10 | 72 |

*Calculations* : The rate curve or the calibration curve of the current metre used here is given by

$$v=1{\cdot}15N \tag{5.5}$$

where $v$ is the velocity in cm/sec and $N$ is the number of revolutions of the cup per minute (r.p.m.).

Table 5.2 Calculations of velocity and discharge of the flowing water in the channel

| *Sub-section* | $N$ (r.p.m.) | $v^{+}$ (cm/sec) | $v$ (m/sec) | *Area of flow(a)* (m²) | *Discharge (av)* (m³/sec) |
|---|---|---|---|---|---|
| *PQ* | 10 | 11·5 | 0·115 | 0·58 | 0·067 |
| *QR* | 33·3 | 61·3 | 0·613 | 1·08 | 0·662 |
| | 20·0 | (average) | | | |
| *RS* | 8·3 | 9·5 | 0·095 | 0·49 | 0·047 |
| | | | | $\Sigma 2{\cdot}15$ | $\Sigma 0{\cdot}776$ |

$^{+}$Using Eq. (5·5).

The total discharge of water through the channel$=0{\cdot}776$ m³/sec

Total cross-sectional area of flow$=2{\cdot}15$ m²

$$\text{The mean velocity of water flow}=\frac{0{\cdot}776}{2{\cdot}15}\text{ m/sec}$$

$$=0{\cdot}36\text{ m/sec}$$

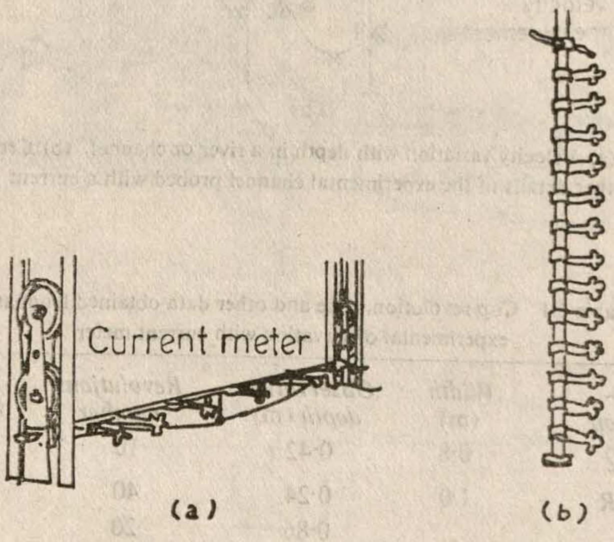


Fig. 5.9. In case of a deep and wide river the current meter may be placed horizontally and vertically as shown in (a) and (b) respectively.

### 5.2.2 DETERMINATION OF VELOCITY AND DISCHARGE IN AN OPEN CHANNEL FLOW BY FLOAT METHOD.

*Theory* : The velocity of water flow is defined as the ratio of the distance covered by a water particle to the time taken. A small wooden or other float thrown into the flowing water may assume the movement similar to that of a water particle.

The velocity in surface water is slightly higher than the remaining bulk of the water (Fig. 5.8a). Hence to find out the mean velocity($v_m$) to be utilised for general calculations the following relation is generally used :

$$v_m = cv_f \tag{5.6}$$

where $v_f$ is the velocity of a float or surface water velocity and $c$ is a constant (0·8 to 0·9) to be chosen suitably in each case.

If $a_A$ and $a_B$ are the cross-sectional areas of water flow at stations $AC$ and $BC'$ (Fig. 5.10), the discharge($Q$) using equation of continuity will be

$$Q = a_A v_m = a_B v_m \tag{5.7}$$

if there is no water loss in between stations $AC$ and $BC'$. But in field channels the loss in general cannot be avoided. Hence, the mean discharge through the channel may be calculated as

$$\text{Mean } Q = \frac{a_A v_m + a_B v_m}{2} \tag{5.8}$$

*Experimental Accessories* : A flowing channel, wooden floats as weightless as practicable, tape, scale, threads, pegs, stopwatch, etc.

*Procedure* : A rectangular shaped brick-built (cement concrete) straight section of a channel (Fig. 5.10) was chosen and stations were marked as $A$ and $B$ (i.e., $AC$ and $BC'$). Pegs were installed at $A$, $B$, $C$, $C'$ in such a way that the two pieces of threads tied on top of the pegs form the lines $AC$ and $BC'$ which are horizontal and perpendicular to the direction of water flow (Fig. 5.10). A wooden float was then thrown in the channel at $A'$. As soon as it reached the $AC$ line the stopwatch was started and the depth of water surface from the thread line $AC$ was measured. The stopwatch was put off when the float reached the line $BC'$ and simultaneously the vertical distance between the thread line $BC'$ and free water surface was measured. The whole process was repeated for 5 to 7 times. The width of the channel, the vertical distance between the thread lines ($AC$ and $BC'$) and the bottom of channel were measured *a priori*. Thus the depths of water flow below $AC$ and $BC'$ lines were suitably obtained.

*Calculations* : The rate curve or the calibration curve of the current metre used here is given by

$$v=1{\cdot}15N \tag{5.5}$$

where $v$ is the velocity in cm/sec and $N$ is the number of revolutions of the cup per minute (r.p.m.).

Table 5.2 Calculations of velocity and discharge of the flowing water in the channel

| *Sub-section* | $N$<br>(r.p.m.) | $v^+$<br>(cm/sec) | $v$<br>(m/sec) | *Area of flow*$(a)$<br>(m$^2$) | *Discharge* $(av)$<br>(m$^3$/sec) |
|---|---|---|---|---|---|
| *PQ* | 10 | 11·5 | 0·115 | 0·58 | 0·067 |
| *QR* | 33·3 | 61·3 | 0·613 | 1·08 | 0·662 |
| | 20·0 | (average) | | | |
| *RS* | 8·3 | 9·5 | 0·095 | 0·49 | 0·047 |
| | | | | $\Sigma$2·15 | $\Sigma$0·776 |

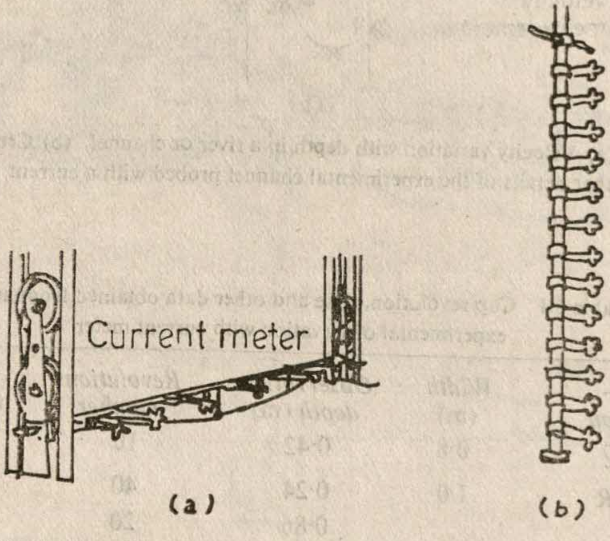
$^+$Using Eq. (5·5).

The total discharge of water through the channel $=0{\cdot}776$ m$^3$/sec

Total cross-sectional area of flow $=2{\cdot}15$ m$^2$

$$\text{The mean velocity of water flow} = \frac{0{\cdot}776}{2{\cdot}15}\ \text{m/sec}$$

$$=0{\cdot}36\ \text{m/sec}$$



(a) (b)

Fig. 5.9. In case of a deep and wide river the current meter may be placed horizontally and vertically as shown in (a) and (b) respectively.

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The velocity in surface water is slightly higher than the remaining bulk of the water (Fig. 5.8a). Hence to find out the mean velocity($v_m$) to be utilised for general calculations the following relation is generally used :

$$v_m = c v_f \tag{5.6}$$

where $v_f$ is the velocity of a float or surface water velocity and $c$ is a constant (0·8 to 0·9) to be chosen suitably in each case.

If $a_A$ and $a_B$ are the cross-sectional areas of water flow at stations $AC$ and $BC'$ (Fig. 5.10), the discharge($Q$) using equation of continuity will be

$$Q = a_A v_m = a_B v_m \tag{5.7}$$

if there is no water loss in between stations $AC$ and $BC'$. But in field channels the loss in general cannot be avoided. Hence, the mean discharge through the channel may be calculated as

$$\text{Mean } Q = \frac{a_A v_m + a_B v_m}{2} \tag{5.8}$$

*Experimental Accessories* : A flowing channel, wooden floats as weightless as practicable, tape, scale, threads, pegs, stopwatch, etc.

*Procedure* : A rectangular shaped brick-built (cement concrete) straight section of a channel (Fig. 5.10) was chosen and stations were marked as $A$ and $B$ (i.e., $AC$ and $BC'$). Pegs were installed at $A$, $B$, $C$, $C'$ in such a way that the two pieces of threads tied on top of the pegs form the lines $AC$ and $BC'$ which are horizontal and perpendicular to the direction of water flow (Fig. 5.10). A wooden float was then thrown in the channel at $A'$. As soon as it reached the $AC$ line the stopwatch was started and the depth of water surface from the thread line $AC$ was measured. The stopwatch was put off when the float reached the line $BC'$ and simultaneously the vertical distance between the thread line $BC'$ and free water surface was measured. The whole process was repeated for 5 to 7 times. The width of the channel, the vertical distance between the thread lines ($AC$ and $BC'$) and the bottom of channel were measured *a priori*. Thus the depths of water flow below $AC$ and $BC'$ lines were suitably obtained.

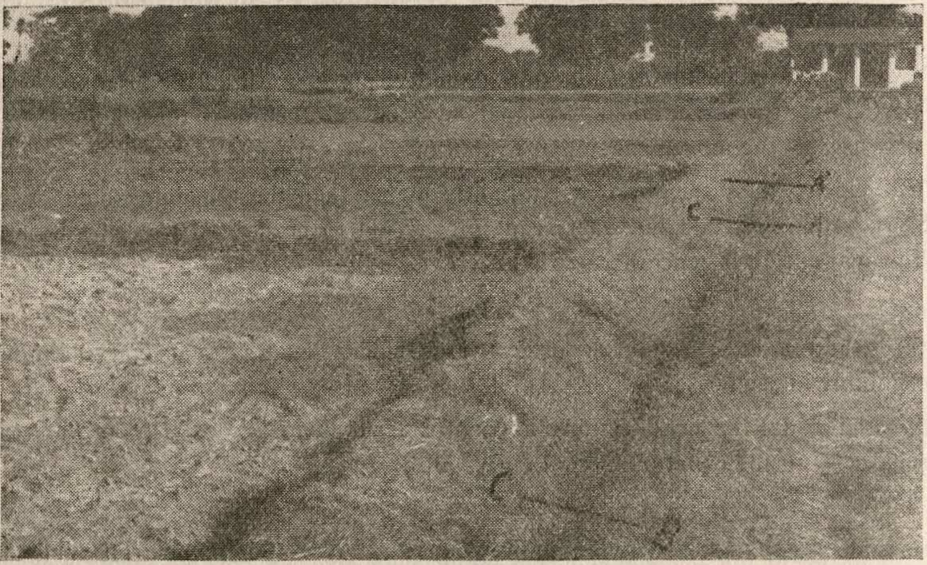


Fig. 5.10. An open channel. The stations *A* and *B* are 50 m apart.

*Observations and Results* :

Table 5.3

| *Float time to cover AB* (second) | *Depth of flow* (cm) | |
|---|---|---|
| | *Station A* | *Station B* |
| 105 | 3·20 | 3·21 |
| 112 | 3·23 | 3·25 |
| 911 | 3·34 | 3·29 |
| 112 | 3·27 | 3·24 |
| 105 | 3·21 | 3·22 |
| 119 | 3·32 | 3·30 |
| $\Sigma$ 672 | $\Sigma$ 19·57 | $\Sigma$ 19·51 |

Channel width $b=0{\cdot}255$ m

Let $t$ be the average time taken by the float to cover the distance *AB*, i.e., 50 metres.

$$\therefore \; t=\frac{672}{6}=112 \text{ sec}$$

$$\therefore \; v_f=\frac{50}{112} \text{ m/sec}=0{\cdot}4464 \text{ m/sec}$$

$$v_m=0{\cdot}85v_f=0{\cdot}3795 \text{ m/sec}$$

Average depth of flow at station $A=\frac{19{\cdot}57}{6}$ cm$=0{\cdot}0326$ m

$$\therefore \; a_A=0{\cdot}255\times 0{\cdot}0326 \text{ m}^2=0{\cdot}0083 \text{ m}^2$$

Average depth of flow at station $B=\frac{19{\cdot}51}{6}$ cm$=0{\cdot}0325$ m

$$\therefore \; a_B=0{\cdot}255\times 0{\cdot}0325 \text{ m}^2=0{\cdot}0082 \text{ m}^2$$

Mean $Q=\frac{v_m}{2}(a_A+a_B)=\frac{0{\cdot}3795}{2}(0{\cdot}0083+0{\cdot}0082)$ m³/sec$=0{\cdot}0031$ m³/sec$=3{\cdot}1$ litres/sec.

### 5.2.3. DETERMINATION OF VELOCITY AND DISCHARGE IN AN OPEN CHANNEL FLOW BY MANNING'S FORMULA.

*Theory* : Velocity of water flowing through an open channel may be determined as

$$v=\frac{1}{n}R^{2/3}S^{1/2} \tag{5.9}$$

where $v$=mean velocity of water flow, m/sec

$R$=hydraulic radius $\left(\frac{a}{P}\right)$, m

$a$=cross-sectional area of flow, m$^2$

$P$=wetted perimeter, m

$S$=channel slope, m/m

$n$=roughness coefficient of the channel surface

The Eq. (5.9) is popularly known as Manning's formula and is widely used for estimating mean velocity of flow in open channels. The discharge($Q$) may then be estimated as

$$Q=av \text{ m}^3/\text{sec} \tag{5.10}$$

*Materials Required* : A flowing channel, scale, tape, pegs, threads, etc.

*Procedure* : The channel referred in Fig. 5.10 was used. This experiment was carried out in the same conditions as described in Article 5.2.2. Thus the cross-sectional area of flow was measured as in Article 5.2.2. Similarly, wetted perimeter was measured following geometric rules depending on the depth of flow.

For slope, the station $B$ was first plugged along the line $BC'$ by earthen bund and water was allowed to get accumulated after which the station $A$ was plugged along the line $AC$ keeping the span $AB$ unaltered. The water flow through the channel was then stopped for a brief period. At mid-points of both $AC$ and $BC'$ the water levels with reference to the bottom of the channel were then measured simultaneously with the help of scales placed vertically. The difference in water levels divided by the length $AB$ was considered as the slope(S) in m/m or its equivalent unit.

The channel surface was inspected. Accordingly, the value of $n$ was chosen from a standard table.

***Observations and results*** :

$S$=0·00712 m/m

$n$=0·019

From Article 5.2.2

$b$=width of the channel bottom=0·255 m

$d_A$=depth of flow at station $A$

=0·0326 m

$d_B$=depth of flow at station $B$

=0·0325 m

$\therefore \quad a_A = 0{\cdot}255 \times 0{\cdot}0326 \text{ m}^2 = 0{\cdot}0083 \text{ m}^2$

$a_B = 0{\cdot}255 \times 0{\cdot}0325 \text{ m}^2 = 0{\cdot}0082 \text{ m}^2$

$P_A = b + 2d_A = 0{\cdot}3302 \text{ m}$

$P_B = b + 2d_B = 0{\cdot}3300 \text{ m}$

$$\therefore \quad R_A = \frac{a_A}{P_A} = 0{\cdot}0251$$

$$R_B = \frac{a_B}{P_B} = 0{\cdot}0248$$

$$v_A = \frac{1}{0{\cdot}019} R_A{}^{2/3} S^{1/2} = 0{\cdot}3807 \text{ m/sec}$$

$$Q_A = a_A v_A = 0{\cdot}00316 \text{ m}^3\text{/sec}$$

Similarly, $v_B = \frac{1}{0{\cdot}019} R_B{}^{2/3} S^{1/2} = 0{\cdot}3777$ m/sec

$Q_B = a_B v_B = 0{\cdot}0031 \text{ m}^3\text{/sec}$

Hence, average velocity of water flow= 0·3792 m/sec

Average discharge$=0{\cdot}00313 \text{ m}^3\text{/sec}$

$=3{\cdot}13$ litre/sec

*Note* : (i) In Eq. (5.9) the symbol $S$ actually stands for the slope of the energy line. In field channels there exists very little difference in $S$ and the slope of the channel bottom which is easy to measure. Hence, $S$ is taken as the slope of the channel bottom.

(ii) In case of a natural (or earthen) channel which is an irregular shaped as in Fig. 5·8b the wetted perimeter is the length of $PqrS$. A thin thread may be placed all along the line $PqrS$ and then stretched and measured as per scale of the drawing.

(iii) In case of high channel slope and irregular bottom or if the flow through channel cannot be stopped the $S$ can be measured by Dumpy level and survey staff, following normal method of surveying.

### 5.2.4 DETERMINATION OF VELOCITY AND DISCHARGE IN AN OPEN CHANNEL FLOW BY CHEZY'S METHOD.

*Theory* : This method is widely used in civil engineering works (purposes) and is described as

$$v = C\sqrt{RS} \tag{5.11}$$

with usual significance of the symbols explained in § 5.2.3. The symbol $C$ is known as Chezy's constant which is equal to $\frac{1}{n} R^{1/6}$ approximately for comparison purposes. The discharge($Q$) may be estimated using Eq. (5.10).

*Materials Required and Procedure* : Same as in § 5.2.3.

*Observations and Results* :

$C=28{\cdot}45$ (from a standard table)

$$\left.\begin{aligned}\text{Average } R&=0{\cdot}0250 \text{ m}\\ S&=0{\cdot}00712 \text{ m/m}\end{aligned}\right| \text{ from § 5.2.3.}$$

Thus $v=28{\cdot}45\sqrt{0{\cdot}025\ (0{\cdot}00712)}$ m/sec

$=0{\cdot}3795$ m/sec

Average $a=0{\cdot}00825$ (from § 5.2.3)

$\therefore$ Average $Q=av=0{\cdot}00313$ m$^3$/sec

$=3{\cdot}13$ lit/sec

## 5.3 DETERMINATION OF THE DISCHARGE OF A TUBEWELL.

*Theory* : The two most accurate and direct methods are Direct Weight Measurement and Calibrated Tank. But it is difficult to note the fluctuations (if any) of the yield at any time with these two methods.

Amongst various indirect methods like the V-notch or Weir, Parshall Flume and Slope Area method are used in the field.

The entire discharge of a tubewell if passed through a 90° V-notch following usual norms of the V-notch the discharge can be determined by noting simply the head of flow over the V-notch (vide § 5.1.1).

*Experimental Accessories* : A tubewell fitted with a pump, stilling tanks fitted with V-notch and its accessories.

*Description of the set-up* : The tubewell discharges into a tank of $4{\cdot}25$ m × $1{\cdot}5$ m × $1{\cdot}5$ m size and has the three compartments (Fig. 5.11). The divider walls have three passageways or openings at the bottom through which water can pass from one chamber to other. The chamber in which delivery pipe of the pump ends has been provided with baffle walls (not shown in the figure). A 90° V-notch is fitted in the wall ($1{\cdot}5$ m × $1{\cdot}5$ m) of the third chamber at the lower end of the tank. The crest of the notch is so levelled that water passing over it is of the same depth at all points along the crest. The total height of the notch is 12 cm. To have a free fall of water from the V-notch a brick-built cement channel of 5 m length with a cross-section sufficient to accommodate the water flow is made just below the notch. A gauge or scale is fixed vertically on the upstream face of the notch at a distance (at least $4H$ away from the notch where $H$ is the head of flow) of about 50 cm. The zero of the scale or gauge and that of the crest is kept on the same plane.

*Procedure* : Same as § 5.1.1

*Experimental Data* : - do -

*Calculations* : - do -

*Note* : 1. The same discharge($Q$) may be directly delivered to a cement-lined channel of 30 m length. The velocity of flow($v$) in between 15-25 m length may be determined by float method or Manning's or Chezy's formula. The discharge can be obtained from $Q=av$ relation where $a$ is the cross-sectional area of flow (vide § 5.2.2 to § 5.2.4).

2. At lower half of the 30 m channel a pre-calibrated Parshall Flume may be installed suitably. Noting the height of flow in the flume and using specific relation $Q$ of the tubewell can be determined.

3. There are many other similar methods.

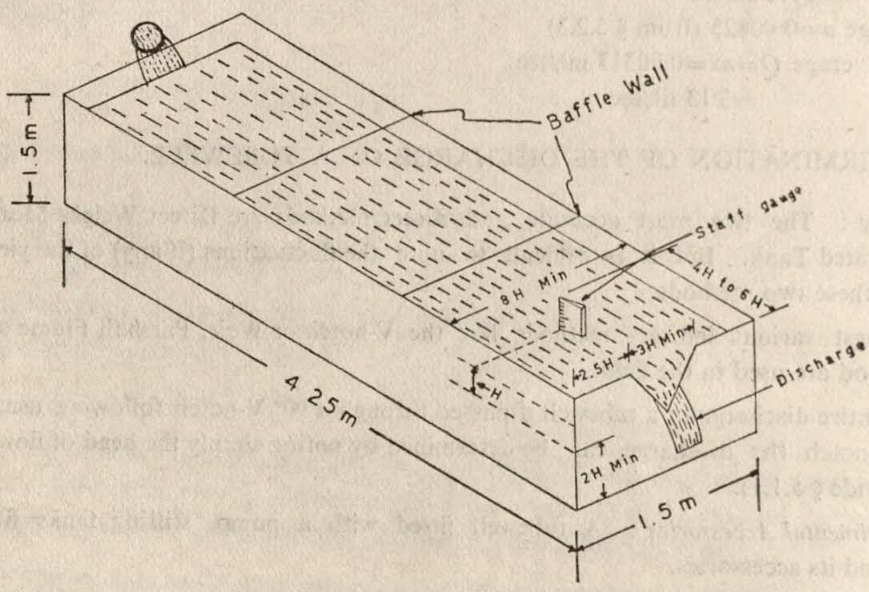


Fig. 5.11. An arrangement to measure the discharge or yield of a tubewell using V-notch. The tubewell is discharging into a tank with two baffle walls.

# 6

# Drainage

## 6.1 DETERMINATION OF DRAINAGE COEFFICIENT

*Theory* : Drainage coefficient is defined as the depth of water (cm or inch) to be removed or drained from the area in 24 hours time period. Very often the drainage coefficient is simply mentioned by depth without any reference to time period ; but it is always implied that the time is 24 hours. Sometimes, it is also designated by the term drainage modulus. The depth of water to be removed from the crop-field will vary with the crop and soil.

In absence of the required data on drainage coefficient it is recommended that 1% of the mean annual rainfall in the area may be assumed as the drainage coefficient.

In any water-logged area if the depth of water is measured today at 9·00 hours as $d_1$ cm and $d_2$ cm on the next day at same hour then the drainage coefficient of the area (land) will be $(d_1-d_2)$ cm. This is the direct measurement method by which the drainage coefficient can be determined.

*Experimental accessories* : A model area as shown in Fig. 6.1 fitted with underdrain(s), bucket, beaker, watch, measuring cylinder.

*Procedure* : A plastic box of 0·5 m × 0·5 m × 0·3 m size with top end open was fabricated in such a fashion that all joints and corners were water tight. A plastic pipe of 1·5 cm diameter having a length of 53 cm was placed at the mid-line of the bottom area providing a mild slope. This pipe was allowed to pass through a hole in one side of the wall. About 3·5 cm pipe length was outside the wall.

The hole through which the pipe (3·5 cm portion) was extended outside was made water tight. The 49·5 cm length of pipe which remained within the box was perforated (at random) *a priori* and one of the open ends was plugged with cloth bundle to prevent the entry of soil through this end. The elevation difference between the outer end and inner end of the pipe was kept as 0·5 cm. The box was then filled with soil collected from a 20 cm depth of surface soil of an agricultural land. Care was taken to place the soil in the box in its natural order and compaction and about 10 cm blank space from the top soil surface to the brim of the plastic box was maintained. This was kept as such for few days in the open atmosphere.

On the day of experimentation the box was placed on a small working table at a height of about 30 cm. A bucket was placed just below the outlet of the plastic pipe. Water was poured slowly over the soil surface up to a height of 9 cm or so. The initial time was noted. After 4 hours the volume of water collected in the bucket was measured.

*Observations and results* :

Volume of water collected =5 lit

Time =4 hours

Area $=50\times 50\ \text{cm}^2$

$$\therefore \text{ Depth drained in 24 hours} = \frac{5\times 6\times 1000}{2500}\ \text{cm}$$

$$=12\ \text{cm}$$

Thus the drainage coefficient of the model area=12 cm.

*Note* : This is a model experiment. Following this procedure it can be done in actual field. Value obtained by the model test will not exactly represent the field value.

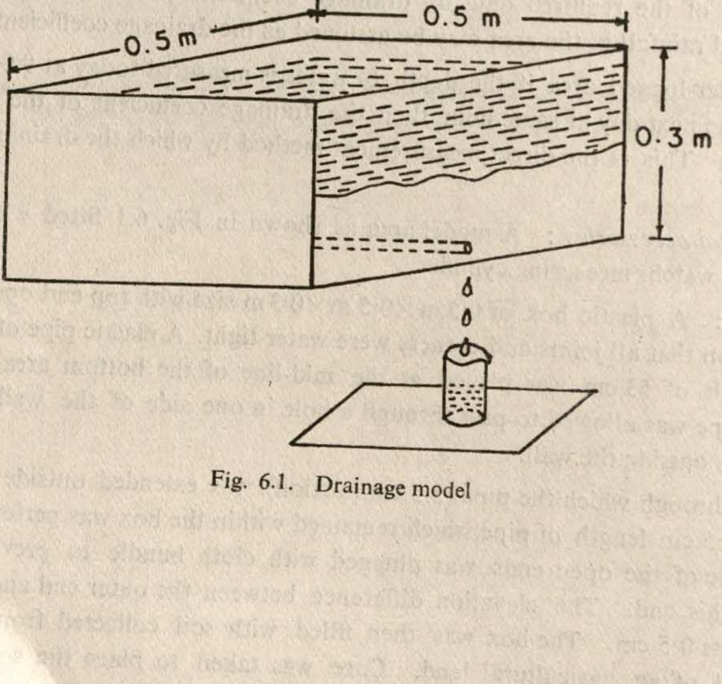


Fig. 6.1. Drainage model

# 7

# Topographic Survey and Earthwork

## 7.1 TOPOGRAPHIC SURVEY

The term topography is used to mean the configuration of the land. Hence a topographic map is a two-dimensional mirror image on a greatly reduced scale of the features of earth's surface.

The convention used in a map is generally given in the Legend. Two intersecting arrows are displayed in each map to indicate North and East directions (magnetic). Generally, its bearings with the geographic North-South are supplied on the lower margin of the map.

Scale is mentioned clearly. This is chosen according to the needs. If the scale is 1 cm=10 km it means that if two points on the map are 1 cm apart, they will be 10 km apart on the ground surface.

A contour line is a line drawn through points having the same altitude above the mean sea level. It is an imaginary line of constant elevation on the surface of the ground and drawn corresponding to a scale on a map. The difference in elevation between each two consecutive contour lines of a map is known as contour interval.

The shore line at mean sea level would be a contour line of zero elevation. Similarly, the shore line of a pond or a lake is a contour line having a particular altitude.

A glance to any nicely-prepared contour map will enable one to understand every features of the land surface, viz., size, shape, steepness, swamps, canals, gullies, roads, forests, etc. Figure 7.1 may be looked into for this purpose.

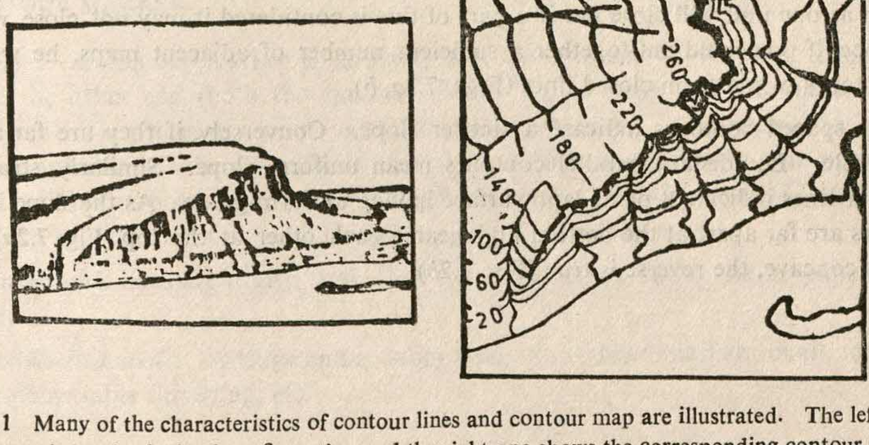


Fig. 7.1 Many of the characteristics of contour lines and contour map are illustrated. The left one is the actual sketch of a land configuration and the right one shows the corresponding contour map.

### 7.1.1 DRAWING A CONTOUR MAP REPRESENTING A HILL AND A POND

*Theoretical Illustrations* : Let us take a small hillock (Fig. 7.2*a*) 50% of which is very steep and the rest is gently sloping. Let us submerge this hillock completely in the water (in sea or lake, etc.). Now raise its top above the water surface. Along the water level a chalk line is drawn ; it is raised further just *y* metre above (vertically). The second chalk line is drawn along the water level. It is raised again *y* metre above. The third chalk line is drawn along the water level. This is continued unless the bottom of the hillock is touched by water level.

Now the hillock is placed on a piece of paper placed on a horizontal surface. Vertical projections are drawn from each point of all the chalk lines on the paper placed below. The hillock is now removed from the paper. Now the contour map is ready (Fig. 7.2*a*).

Similarly, let us take a small pond full of water. A chalk line is drawn along the shore line. Now pump out a certain volume of water till the fall in water level is *y* metre. The second chalk line is drawn along the water level. This is continued till it touches the pond bottom. Now the empty pond is placed on a piece of paper and the process as mentioned in the second paragraph is completed till the Fig. 7.2*b* is obtained. Here *y* metre is the contour interval.

*Materials Required* : Paper, pencil and geometrical instruments.

*Procedure* : Following the principles described in the theoretical illustration contour maps for an assumed hillock (Fig. 7.2*a*) and a pond (Fig. 7.2*b*) were drawn hypothetically.

*Observations* : We have a series of closed contour lines on the paper which are spaced comparatively far apart on the side with gentle slope and close together on the side with steep slope. The values of vertical interval, i.e., contour intervals between two successive contour lines remain to be 5 m (i.e., $y=5$ m). The successive inside contours have higher value in case of a hill and lower values in case of a pond.

*Discussion and Conclusions* : Every contour is a continuous and closed line. But if the hillock or the pond is divided vertically into two parts, the contour of each part could not have closed within the map. Similarly, since the earth surface is a spherical one the contour of the entire earth as one unit will close but if a part of this is considered it may not close within the map. Hence, if one could put together a sufficient number of adjacent maps, he would find that all contours would form closed lines (Figs. 7.2*a*, *b*).

Closely spaced contours indicate a steeper slope. Conversely, if they are far apart, the slope is gentle. Equidistant parallel contours mean uniform slope. Similarly, straight parallel contour lines indicate a plane land surface having uniform grade. As the slope is convex, the contours are far apart at the bottom and nearer each other at the top (Fig. 7.2*a*). When the slope is concave, the reverse is true (Fig. 7.2*b*).

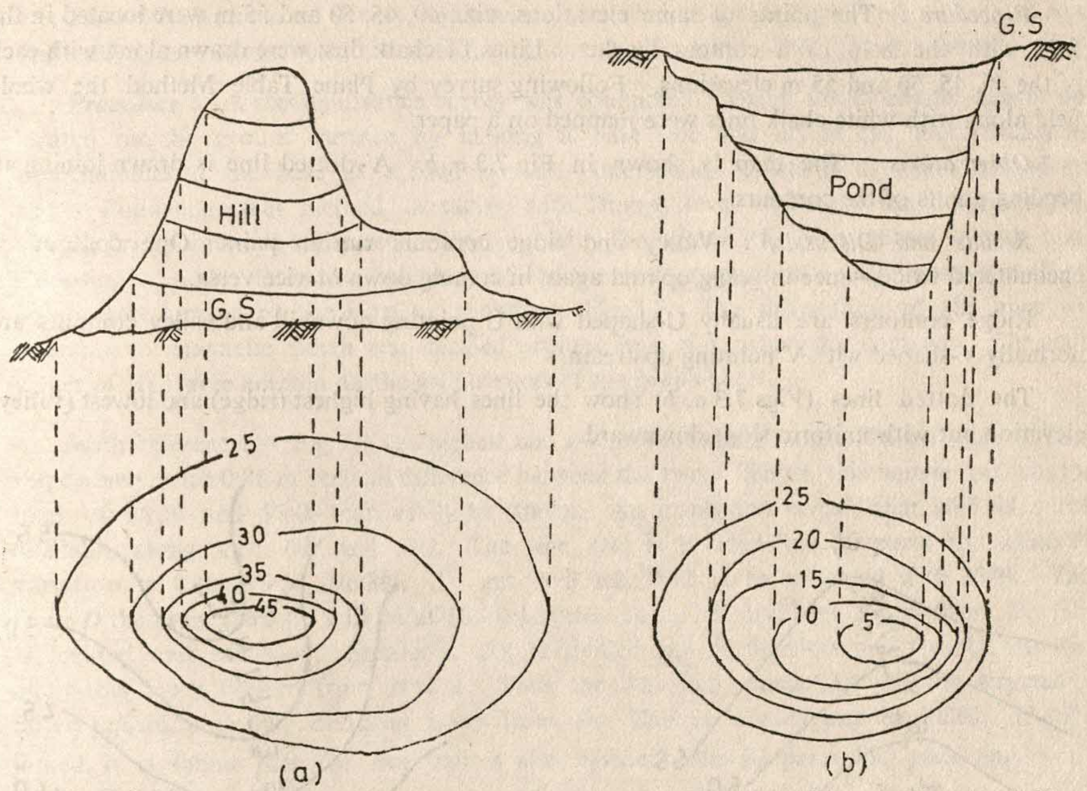


Fig. 7.2. Contour maps for (a) a hill and (b) a pond, where the reduced level of the ground surface is 25 m.

Two contour lines never cross each other or touch. The reason behind this is that the point of intersection (or touch) will then have two different elevations which is absurd. In the present exercise there were no vertical or overhanging cliff for which cases two contours may touch or cross each other.

### 7.1.2 DRAWING OF A CONTOUR MAP REPRESENTING A RIDGE AND A VALLEY USING A CONTOUR MARKER.

*Theory* : A contour marker is an equipment the one end of which is fixed at a bench mark and the other end (both the ends are joined by a long flexible plastic pipe and filled with water) is placed at a point whose elevation is required. Comparing the difference in water levels at both ends the elevation of any point is known. Similarly, the other end may be shifted unless the points of same elevation is obtained. Thus in the field points of same elevation can be located and a white line with chalk dust can be drawn.

When all such lines are drawn and their projections are taken on a paper, the map is obtained.

*Materials Required* : A ridge and a valley land, a contour marker, chalk dust, equipments for plane table surveying, etc.

*Procedure* : The points of same elevations, viz., 40, 45, 50 and 55 m were located in the field with the help of a contour marker. Lines of chalk dust were drawn along with each of the 40, 45, 50 and 55 m elevations. Following survey by Plane Table Method the whole field along with white chalk lines were mapped on a paper.

*Observations* : The map is shown in Fig 7.3 *a*, *b*. A dotted line is drawn joining all bending points of the contours.

*Results and Discussion* : Valley and ridge contours run in pairs. One contour is encountered twice—once in going up and again in coming down or vice versa.

Ridge contours are usually U-shaped with U pointing downhill and valley contours are normally V-shaped with V pointing upstream.

The dotted lines (Figs 7.3 *a*, *b*) show the lines having highest (ridge) and lowest (valley) elevation but with uniform slope downward.

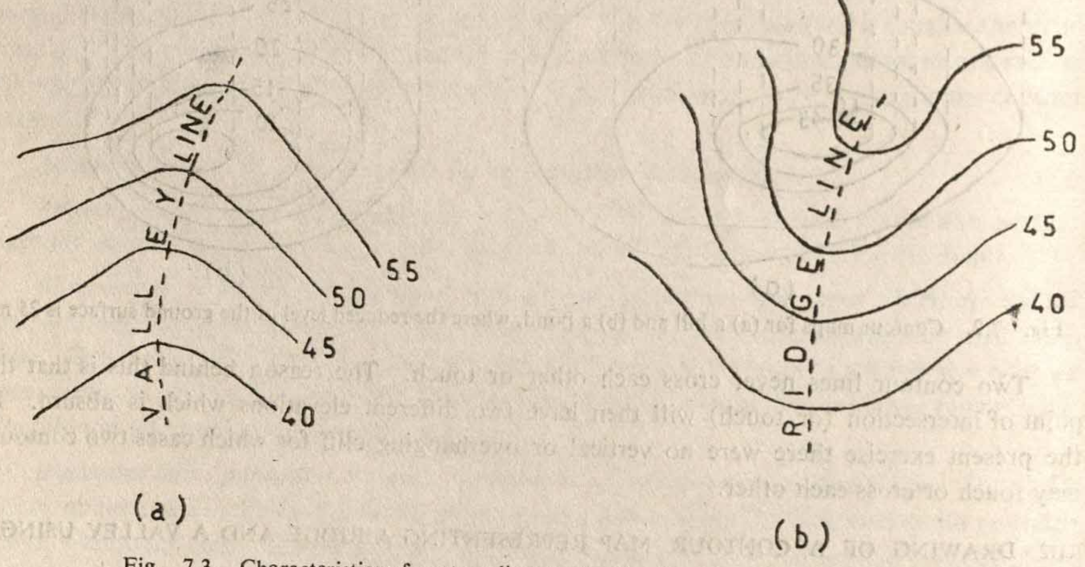


Fig. 7.3. Characteristics of contour lines : (a) valley line, (b) ridge line.

### 7.1.3 CONTOUR SURVEY OF AN AREA.

*Theory* : Among several methods, the grid system is convenient for flat topography. The whole area may be divided into squares of convenient size by chaining and pegs installed at each corners commonly known as "grid points". The size of the square is to be decided in such a manner that there is linear variations in the altitudes (RLs) along any side and diagonals of the chosen square. Land survey with the help of Dumpy level is to be conducted to determine the RL at each grid. Thus a number of RLs at specified points will be available and mapped on graph sheet with a smaller but suitable scale. Points of equal elevations may now be located following unitary method and joined by a free-hand smooth line.

*Materials Required* : Survey equipments, viz., chain, tape, Dumpy level with stand, levelling staff, pegs, ranging rods, cross staff, magnetic needle, graph sheet, pencil, scale, etc.

*Procedure* : A reconnaissance survey was conducted. Using survey chains squares were located on the ground surface by making a base line and laying out lines parallel and perpendicular to the base at a fixed interval. Intersection points (grids) were marked with pegs. Following usual method of survey with Dumpy level and staff, the elevations (RLs) at each grid point were measured comparing with the actual RL of a chosen bench mark. Choosing a scale the entire boundary of the area was mapped on a graph sheet and all grid points were located on the map as shown in Fig 7.5. The orientation of the area with reference to magnetic north was decided with the help of a rectangular compass. The actual values of RLs were entered on the grid corners of the graph sheet.

With reference to Fig 7.4 the highest and lowest available RLs are 97·24 m and 96·38 m, respectively, with 0·86 m vertical difference between the two. Within this square two contour lines of 96·50 and 97·00 can easily be drawn. An inspection reveals that 96·5 RL will be available along *AD*, *DB* and *DC*. The line *DC* is divided into 50 parts for which RL variation is 0·16 (96·54—96·38). To get 96·5 RL 0·12 is to be added with 96·38. Thus from *D* the point (96·5 m) will be at $50 \times 0{\cdot}12/0{\cdot}16$, i.e., 37·5 divisions away from *D*. This is located and encircled. Similarly, *DA* is divided into 50 divisions and the RL variation along this line is 0·86 m from *D* to *A*. Thus the RL 96·5 along *DA* will be situated at $50 \times 0{\cdot}12/0{\cdot}86$, i.e., 6·97 divisions away from *D*. This is located and encircled. If *DB* is joined, it is found that the line *DB* is also divided into 50 parts but each part is $\sqrt{2}$ (i.e., $\sqrt{1^2+1^2}$) times greater than each division along *DC* and *DA*. It does not matter so far locating the suitable RLs along *DB* are concerned. Following the same method as described above the point of 96·5 RL along *DB* is located at $50 \times 0{\cdot}12/0{\cdot}40$, i.e., 15 divisions away from *D*. Now these three points of same elevations are joined by a smooth free-hand curve. It may be noted that there cannot exist points of 96·5 m RL along *AB*, *BC* an *AC*.

Next comes locations of points having elevations of 97·0 m. It exists along *BA*, *CA*, *DA* and nowhere else. These points are situated at $50 \times 0{\cdot}24/0{\cdot}46$, i.e., 26 div, $50 \times 0{\cdot}24/0{\cdot}70$, i.e., 17·1 div and $50 \times 0{\cdot}24/0{\cdot}86$, i.e., 14 div away from *A* along *AB*, *AC* and *AD* respectively. These are encircled and joined by a smooth free-hand curve. In the final map (Fig. 7.5) the encircled points are rubbed off and the contour lines are made firm for easy visualisation.

One of the contour lines is extended a bit outside the boundary and in another the line is broken within the given area to leave a space for writing the value of the contour (Fig. 7.4).

Following the above-mentioned procedures all the contour lines in Fig. 7.5 are drawn. In case more than three points are available on the sides of the squares there is no need to locate exact positions of the points along diagonals, except for those cases where there is some doubt about the concavity or convexity of the lines. So, Fig. 7.5 is a final contour map of the area chosen for this purposes.

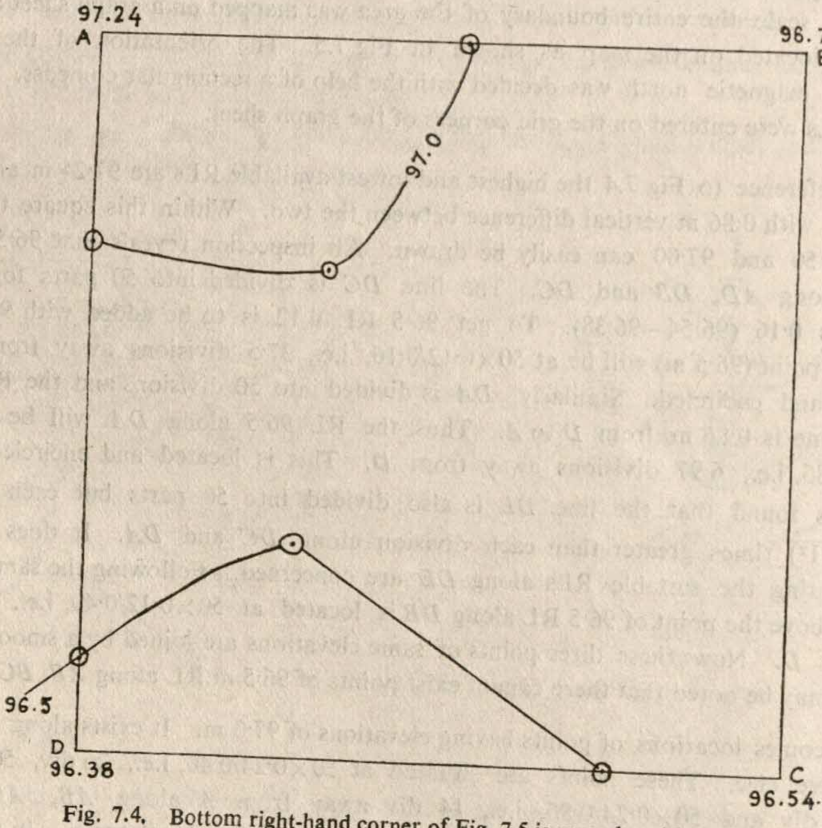


Fig. 7.4. Bottom right-hand corner of Fig. 7.5 is reproduced here to illustrate the procedure for drawing of contour lines

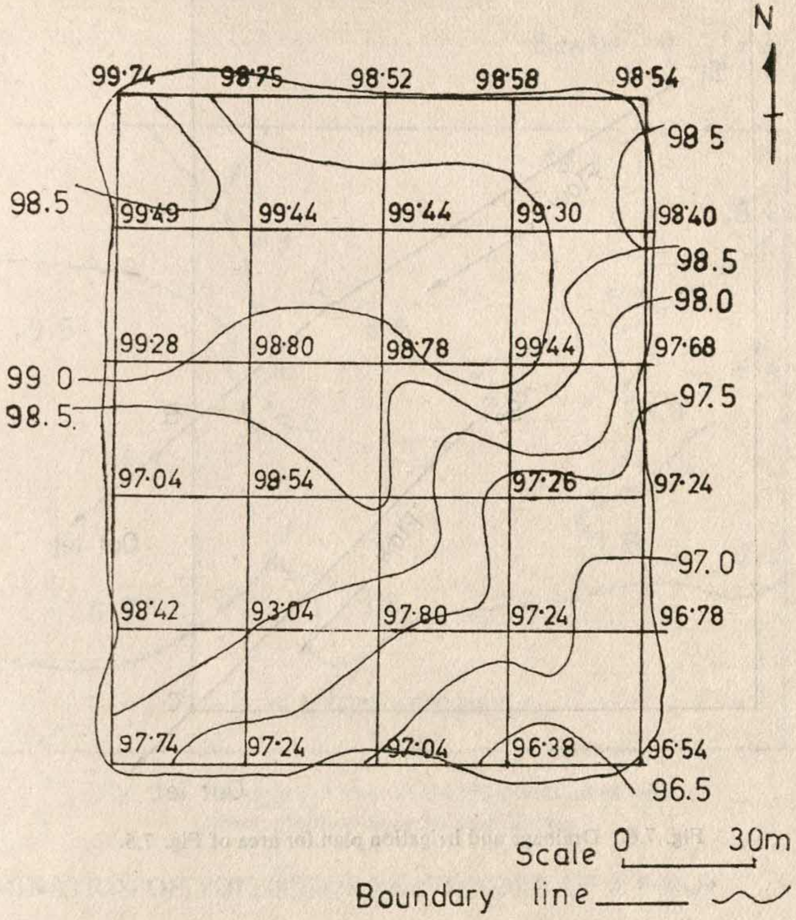


Fig. 7.5. Contour map (vide § 7.1.3)

*Results and Discussion* : A glance to the Fig. 7.5 reveals that the areas enclosed by 98·0 m and 98·5 m ; 99·0 m and 99·5 m contour lines are comparatively flatter than the rest of the land. The ground surface is steepest towards N-E direction along the 97·24-99·44 line (vide mid square along right-hand column).

If the problem of this land is drainage, then drain lines can be laid along $S_1AB$ and $S_2C$ as shown in Fig. 7.6. But if irrigation is the main need of this piece of land, the channels along $S_1AB$ and $S_2C$ may be used but the source of water is to be located at $S_1$ and $S_2$ for gravity delivery into these channels from where the water may be diverted along N-E and S-W directions. In addition to this there may exist various other alternatives (drainage and irrigation network) also.

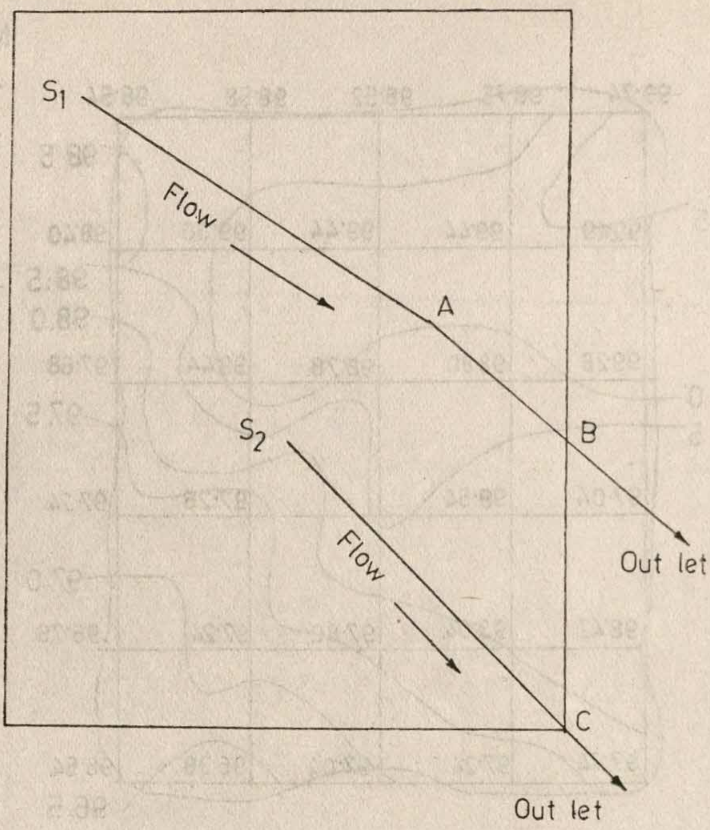


**Fig. 7.6. Drainage and irrigation plan for area of Fig. 7.5.**

### 7.1.4. LABORATORY EXERCISES

1. Make a topographic map of an area of 200×100 metres situated on the hill having some hill like curvature. The area is a terraced (bench) land. Each bench is of 3 m width and vertical interval from bench to bench is 1 m.

2. An area of 100×50 metres has a 4% slope but perfectly a graded land. Draw a contour map for this area using a contour interval of 1 m.

3. Make a tracing of the Fig. 7.7. Draw appropriate contour lines into the sketch. The figures against each dot within the area indicate their RLs in metre.

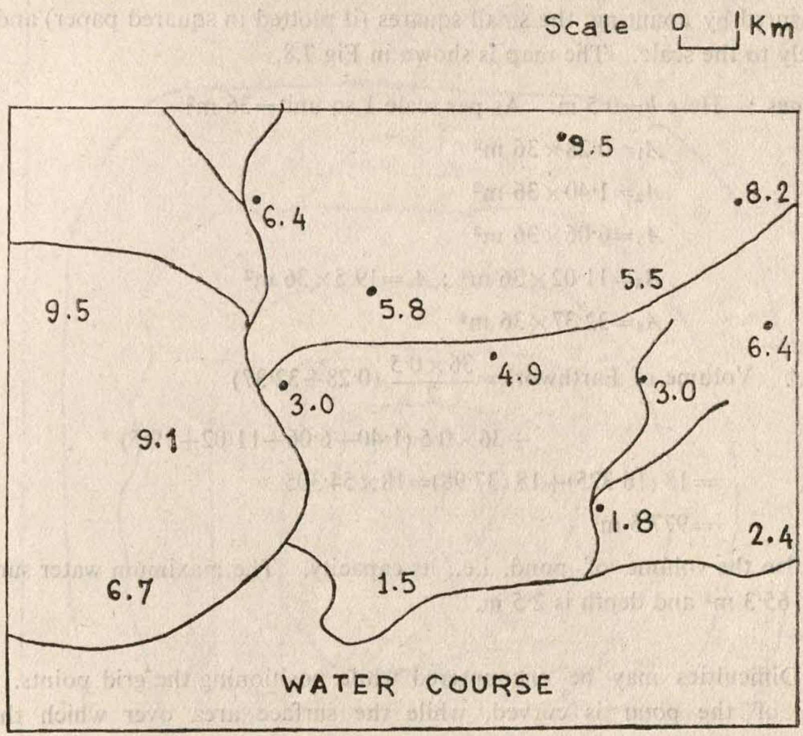


Fig. 7.7. Elevations of some of the site-points along with stream positions in an watershed area.

## 7.2 DETERMINATION OF VOLUME OF EARTHWORK OF A POND

*Theory* : Suppose an empty pond is filled up with water up to a height of few centimetres from the bottoms and water surface area is $A_1$. The height of water is raised by $h$ m above this. The water surface area is noted to be $A_2$. The water level is raised further $h$ m above it to get $A_3$ as water surface area. This is continued up to $A_6$ when the water level is up to the brim. The volume ($V$) of water in the pond may then be obtained as (this $V$ is also the earthwork of pond) :

$$V=\frac{A_1+A_2}{2}h+\frac{A_2+A_3}{2}h+\frac{A_3+A_4}{2}h+\frac{A_4+A_5}{2}h+\frac{A_5+A_6}{2}h$$

$$=\tfrac{h}{2}\left[A_1+2(A_2+A_3+A_4+A_5)+A_6\right]$$

$$=\tfrac{h}{2}(A_1+A_6)+h(A_2+A_3+A_4+A_5) \qquad (7.1)$$

The shore lines of water levels along the periphery of the pond bank are contour lines. Hence, if the pond is surveyed and a contour map is prepared with a contour interval of $h$ m, the same result can be obtained. For generalisation $A_6$ may be taken as $A_n$.

*Equipment* : Same as in § 7.1.3.

*Procedure* : Same as in § 7.1.3 with 6 m as sides of the squares made for girds. The areas are measured by counting the small squares (if plotted in squared paper) and converting it appropriately to the scale. The map is shown in Fig 7.8.

*Calculations* : Here $h=0{\cdot}5$ m. As per scale 1 sq unit$=36$ m$^2$

$$A_1=0{\cdot}28\times 36 \text{ m}^2$$

$$A_2=1{\cdot}40\times 36 \text{ m}^2$$

$$A_3=6{\cdot}06\times 36 \text{ m}^2$$

$$A_4=11{\cdot}02\times 36 \text{ m}^2 \text{ ; } A_5=19{\cdot}5\times 36 \text{ m}^2$$

$$A_6=32{\cdot}37\times 36 \text{ m}^2$$

$$\therefore \text{ Volume of Earthwork}=\frac{36\times 0{\cdot}5}{2}(0{\cdot}28+32{\cdot}37)$$

$$+36\times 0{\cdot}5\,(1{\cdot}40+6{\cdot}06+11{\cdot}02+19{\cdot}5)$$

$$=18\,(16{\cdot}325)+18\,(37{\cdot}98)=18\times 54{\cdot}305$$

$$=977{\cdot}5 \text{ m}^3$$

This is also the volume of pond, i.e., its capacity. The maximum water surface area of the pond is 1165·3 m$^2$ and depth is 2·5 m.

*Note* : Difficulties may be encountered while positioning the grid points. The inside surface area of the pond is curved, while the surface area over which the grids are supposed to be placed should be more or less flat and approximately horizontal. This means that the grids are to be positioned with reference to the topmost water surface area of any pond, the area of which is little bit less than the inside curved area of the pond. The grid points fixed over the curved surface, if projected on the top water surface will make smaller squares based on which the contour map has been prepared (each side of the square on the curved surface was 6 m, while it is less on the top water surface or horizontal plane). Hence, the calculated areas (viz, $A_1$, $A_2$, $\cdots$, $A_6$) are over-estimated. Accordingly, the volume of earthwork is also an over-estimated figure. The error for the present case may be estimated as follows.

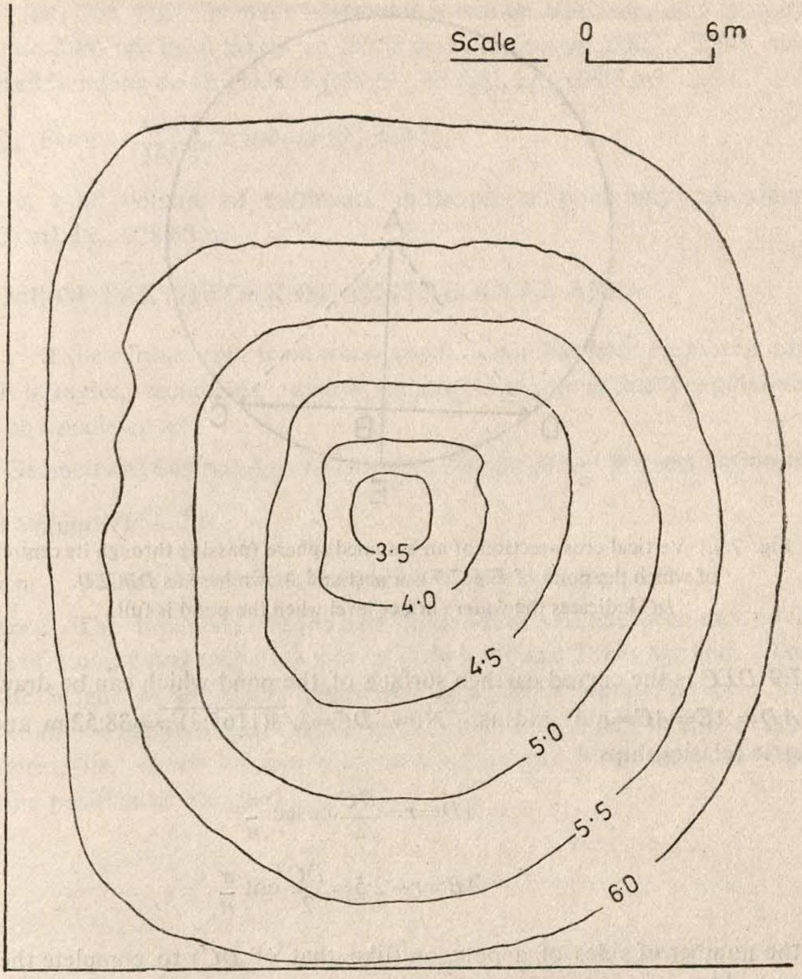


Fig. 7.8. Contour map of a pond recently excavated

It may be assumed that the inside surface area of the pond is a part of the surface area of a sphere, though not exactly. Accordingly, the top water surface area will be a circular one, if the pond has not been constructed specifically with a different geometric shape. It appears from the case as revealed in Figs. 7.8 and 7.9 that both the above two assumptions may be accepted.

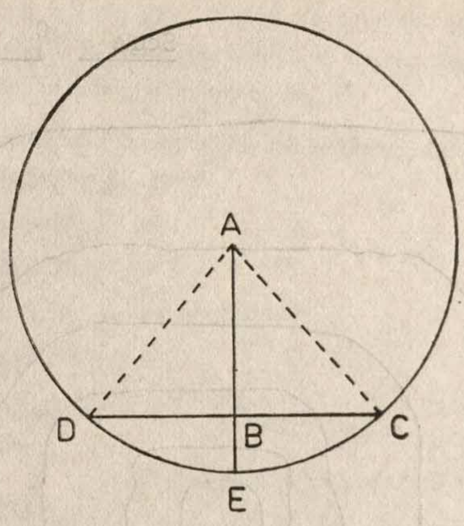


Fig. 7.9. Vertical cross-section of an assumed sphere (passing through its centre) of which the pond of Fig. 7.7 is a part and shown here as *DBCED*. *DC* indicates the water surface level when the pond is full.

In Fig 7.9 *DEC* is the curved earthen surface of the pond which can be drawn with *A* as centre and $AD=AE=AC=r$ as radius. Now $DC=\sqrt{4(1165{\cdot}3)/\pi}=38{\cdot}52$ m and $BE=2{\cdot}5$ m. From geometric relationships

$$AD=r=\frac{DC}{2}\operatorname{cosec}\frac{\pi}{n}$$

$$AB=r-2{\cdot}5=\frac{DC}{2}\cot\frac{\pi}{n}$$

where $n$ is the number of sides of a polygon (like that of *DC*) to complete the circular area (Fig 7.9) from inside.

$$\therefore\quad r^2=\frac{DC^2}{4}\operatorname{cosec}^2\frac{\pi}{n}=\frac{DC^2}{4}\left(1+\cot\frac{2\pi}{n}\right)$$

$$=\frac{DC^2}{4}+AB^2=\frac{DC^2}{4}+(r-2{\cdot}5)^2$$

simplifying $r=75{\cdot}44$ m

$$\text{Hence } 75{\cdot}44=\frac{38{\cdot}52}{2}\operatorname{cosec}\frac{\pi}{n}$$

i.e., $\frac{\pi}{n}=14{\cdot}8^\circ$ or $n=12{\cdot}0$

The *n*th part of the circumference of the circle is

$$\frac{2\pi(75{\cdot}44)}{12}=39{\cdot}5 \text{ m}$$

Thus if the line *DEC* is made horizontal it will be *DBC*, i.e., 39·5 m in length. But in the present case *DBC* has been taken as 38·52 m to represent *DEC*. Thus maximum extra area considered in laying down grids is $\frac{\pi}{4}(39\cdot5^2-38.52^2)$, i.e., 60·05 m²

$$\therefore \quad \%\ \text{Error}=\frac{60\cdot05}{1165\cdot37}\times100=5\cdot15\%\simeq5\%$$

Therefore, total volume of earthwork in the present pond may approximately be taken as 0·95(977·5) m³, i.e., 928·63 m³

## 7.3 VOLUME OF EARTHWORK OF AN IRREGULAR AREA.

*Theory* : If the surface area from where earth or soil has been excavated can be divided into several triangles, rectangles, squares or any other geometrically regular-shaped area the volume can be calculated as

$V_i$=(Geometrical Surface Area)×(Average Height of the Witness within the Area)

$$\text{Total Volume } (V)=\sum_{1}^{n} V_i \tag{7.2}$$

*Equipment* : Plane table and its accessories, plumb bob, tape, etc.

*Procedure* : The boundary of the area from where soil had been excavated was mapped using a scale of 1 unit equal to 3 metres (Fig. 7.10) by Plane Table Method. There were eight witnesses, the height of each was measured by a plumb bob and a tape. The dotted lines were drawn to divide the whole area into a rectangle and five triangles (Fig. 7.10). The height of each witness, i.e., depth of cut in metre was recorded in the map itself against the open circles showing position of witnesses.

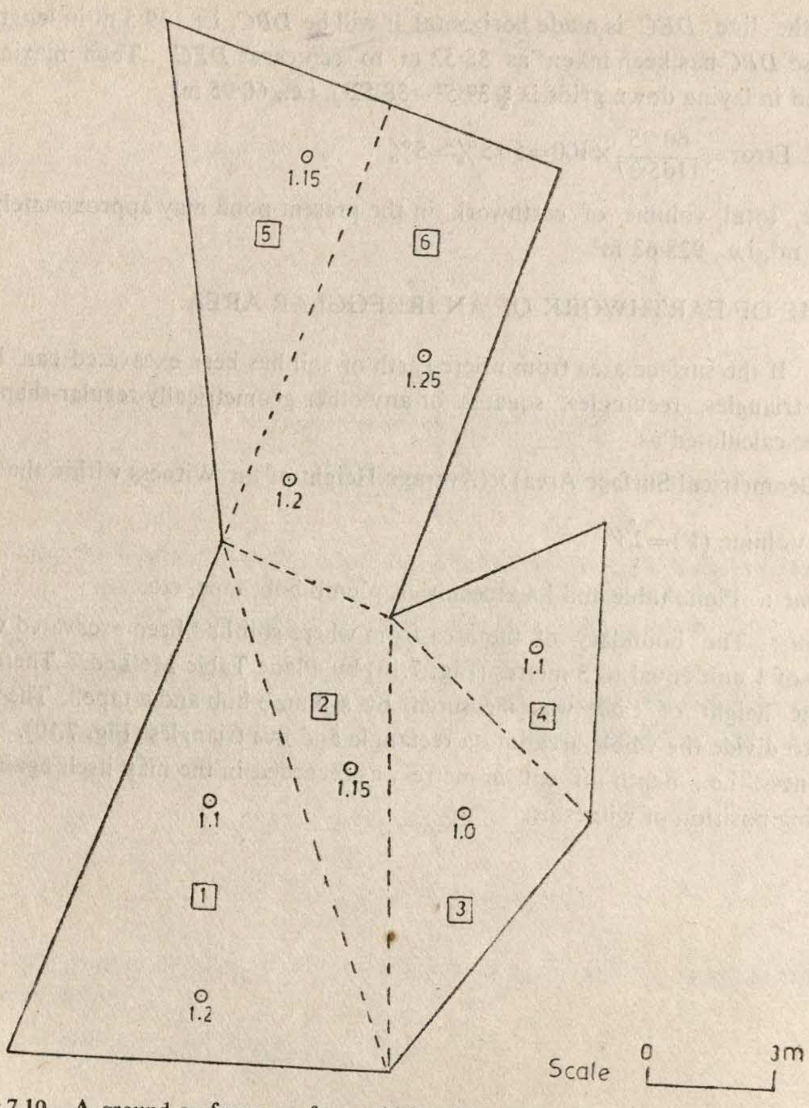


Fig 7.10. A ground surfacc area from which soil has been taken out and witnesses (⊙) are standing. Figures against each circle indicate the height in metre of the witness. Solid lines are boundary lines of the area.

*Calculations* : Area (△) of triangle is given by

$$\triangle=\sqrt{S(S-a)(S-b)(S-c)} \tag{7.3}$$

where $a$, $b$, $c$ are the lengths of the three sides of a triangle and $S$ is the half of the perimeter. The other details are shown in Table 7.1.

The total earthwork volume$=220{\cdot}267$ m$^3$

Table 7.1. Earthwork calculations

| *Section* | *Length unit as per Fig 7·9* | | | | *Area of Cut in Fig 7·9* (Sq. unit) | *Actual Surface Area* (m$^2$) | *Witness Height* (m) | *Average Witness Height* (m) | *Earth*-work* (m$^3$) |
|---|---|---|---|---|---|---|---|---|---|
| | *a* | *b* | *c* | *s* | | | | | |
| 1 | 3·00 | 4·20 | 4·25 | 5·725 | 5·92 | 53·28 | 1·10<br>1·20 | 1·150 | 61·272 |
| 2 | 4·20 | 3·50 | 1·55 | 4·625 | 2·61 | 23·49 | 1·15 | 1·150 | 27·014 |
| 3 | 3·50 | 2·50 | 2·20 | 4·100 | 2·73 | 24·57 | 1·00 | 1·000 | 24·570 |
| 4 | 2·20 | 2·25 | 1·90 | 3·175 | 1·91 | 17·19 | 1·10 | 1·100 | 18·810 |
| 5 | 4·05 | 3·58 | 1·95 | 4·790 | 3·49 | 31·41 | 1·15 | 1·150 | 36·122 |
| 6 | 1·33 | 3·58 | × | × | 4·76 | 42·84 | 1·20<br>1·25 | 1·225 | 52·479 |
| | | | | | | | | | Σ220·267 |

* Actual area (m$^2$) × Depth of cut (m) or average witness height (m)

*Note* : 1. In case the surface area cut is very much irregular the boundary can be mapped by Plane Table Method (or any other suitable survey method) directly on graph (or it can be traced on graph sheet from plane drawing sheet or paper). The area of cut can be found out by planimetering and checked by counting the squares. Other procedure remains same. The photographic view of a planimeter is given in Fig. 7.11.

*Note* : 2. In case of an earthen channel the cross-sectional area may be found out geometrically (or following the method explained in § 5.2.1) at intervals of a distance (so long the channel is more or less uniform). The volume may then be determined as average of the two cross-sectional areas multiplied by their distance plus the next one, etc.

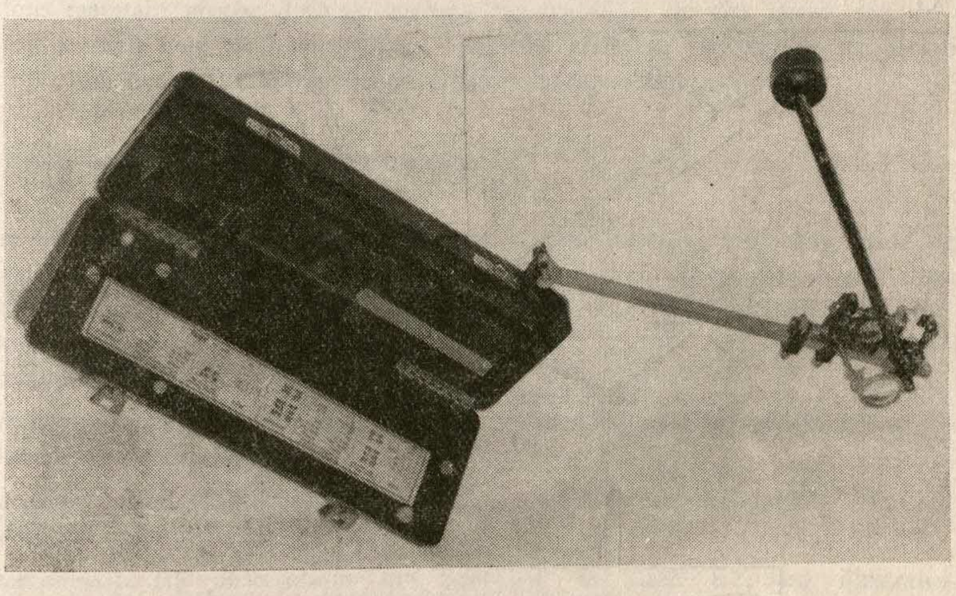


Fig 7.11. A planimeter to measure the area.

# 8

# Traditional Tools and Implements

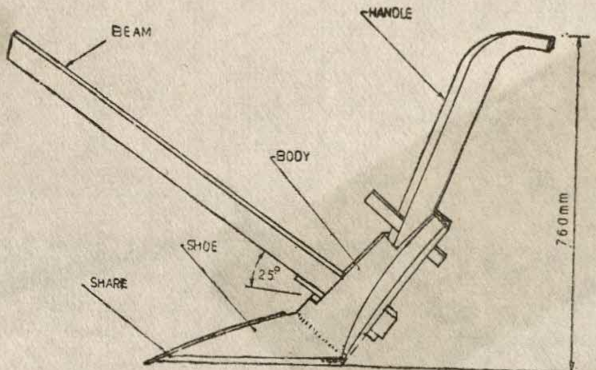
## 8.1 INDIGENOUS PLOUGH

The indigenous plough is the most common implement used by the farmers in India. It is also known as wooden plough or country plough. In addition to ploughing this implement with special attachment is used for line sowing of crops, interculture operations and harvesting of root crops. The common type of yokes used in India to harness the animal power are neck yokes.

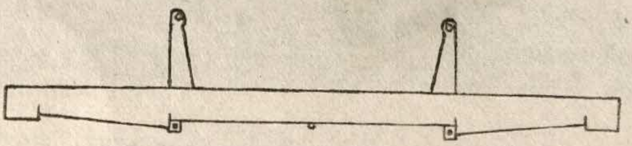
*Materials Required* : An indigenous plough, yoke, scale, tape and hammer, etc.

*Procedure* : The different components of the plough were studied and their dimensions were measured to draw a figure. The materials of different components were examined.

*Observation* : The main components of the plough noted are (i) share, (ii) shoe, (iii) body, (iv) handle and (v) beam. This is illustrated in Fig. 8.1. The dimensions and other details are presented in Table 8.1. A double neck yoke for bullocks is also illustrated in Fig. 8.1.



(a) Plough



(b) Yoke

Fig. 8.1 Indigenous plough and yoke

*Discussion* : The shoe and body are made of one piece of wood in Bihar, Karnataka, Kerala, Maharashtra, Orissa, Tamilnadu and West Bengal. In alluvial soil, the shoe wears out quickly. Therefore, in such areas the shoe and body are made as separate parts to facilitate the replacement of the shoe when worn out. The handle is either provided separately or as an integral part of the body. In some places the shoe, body and handle are made of one piece of wood. The size of the plough and beam vary according to the size of the animals.

Table 8.1 Dimensions and other details of the indigenous plough

| *Serial No.* | *Item* | *Dimensions* | *Material* |
|---|---|---|---|
| 1 | Share, cm × cm × cm | 40×3·5×2·5 | Mild steel |
| 2 | Shoe, cm × cm × cm | 32×25×10 | Wood |
| 3 | Body, cm × cm × cm | 40×22×11 | Wood |
| 4 | Handle, cm × cm × cm | 59×9×6 | Wood |
| 5 | Beam, cm × cm × cm | 200×6×4·5 | Wood |
| 6 | Angle between the shoe and body | 120° | — |
| 7 | Inclination of the share to the ground | 12° | — |

The yoke consists of a smooth round beam which is tappered and rounded at the ends. It is made of Sal wood. The yoke has a small projection at the centre to which the beam of the implement is attached by rope or chain. On either side from the centre of the yoke, wooden sections have been inserted which project downwards at right angles. These projections maintain proper distance between the animals. At the lower end of each projection a small hole has been drilled. The yoke is kept in position on the neck of the animal by a rope tied to the nearest end of the yoke through this hole.

## 8.2 GRAIN HARVESTING TOOL (SICKLE)

The harvesting of almost all the field crops is done manually by locally made sickles. The sickles used in different regions of the country are of various shapes and sizes. In the last five years a lot of research work have been carried out on sickles to improve the ease of operation, efficiency and durability. Accordingly, a number of improved sickles have been developed.

*Materials Required* : Local sickle, improved sickle (Krishi Udyoga sickle), steel tape, scale, pan balance, callipers, etc.

*Procedure* : Both the local and improved sickles were scrutinised. The relevant dimensions and weights were noted down.

*Observation* : The observations are presented in Table 8.2 and illustrated in Figs. 8.2 and 8.3.

Table 8.2 Specifications of local and improved sickles

| *Serial No.* | *Item/ description* | *Local sickle* | *Improved sickles* |
|---|---|---|---|
| 1 | Make | Local Blacksmith | Maharashtra Agro Industries Development Corporation Ltd |
| 2 | Model | Local | Krishi Udyoga |
| 3 | Manufacturing process | Cutting edge is shaped by hot forging and tooth formation with die | Cutting edge is formed with serration die |
| 4 | Material | | |
| | (a) Blade | Mild steel | EN 9 steel Carbon 0·55%, Mn 0·68% Hardness HRB 89 |
| | (b) Rivet | Mild steel | Mild steel |
| | (c) Handle | Wood | Wood |
| 5 | Pitch of teeth | Not uniform | 4 Nos./cm |
| 6 | Weight | 200 gm | 100 gm |

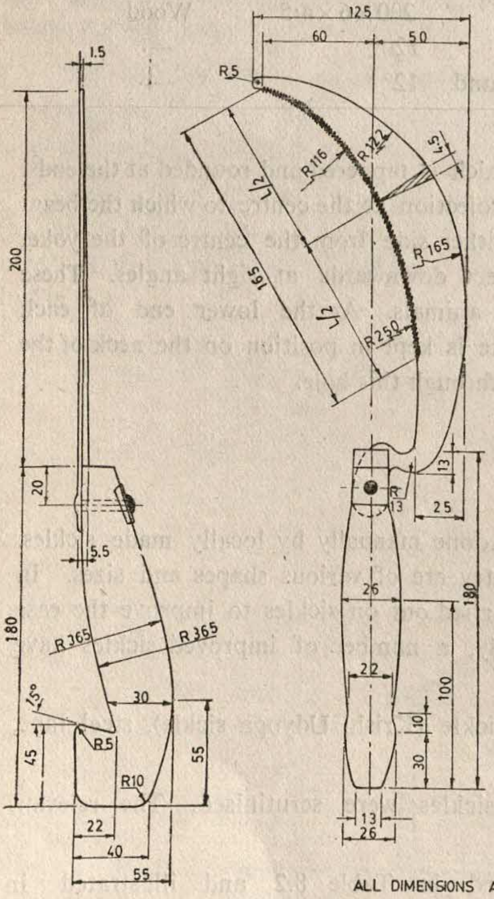


Fig. 8.2. Local sickle

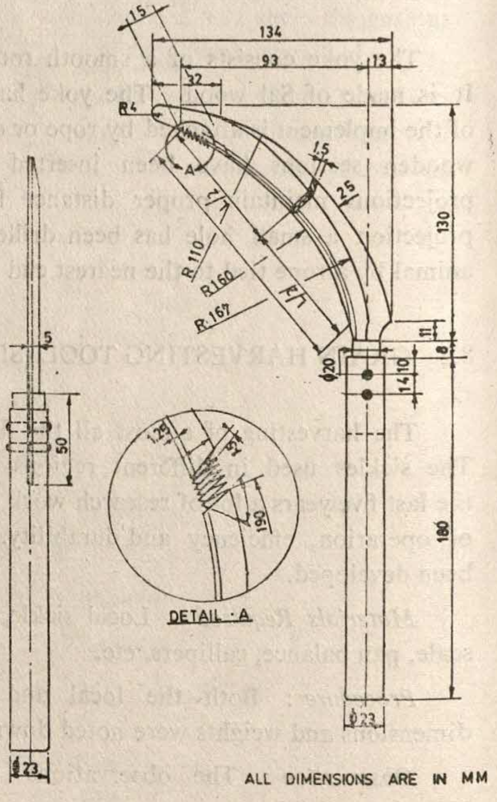
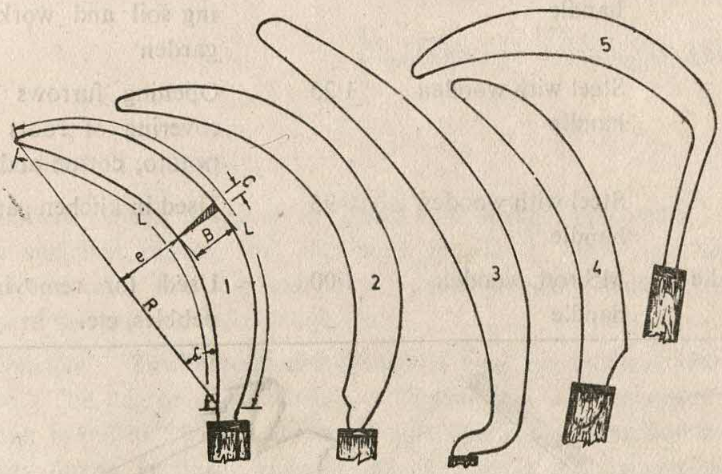


Fig. 8.3. Krishi Udyoga sickle

*Remarks* : At present a number of improved sickles, such as Naveen, Punjab and GAIC sickle are available in the market. The Naveen and GAIC sickle are being manufactured by the Central Institute of Agricultural Engineering, Bhopal and the Gujarat Agro Industries Corporation, Ahmedabad, respectively.

Fig. 8.4 may be looked into for diagrams of five more sickles.



L=Length of blade arc (outer)
L′=Effective length of bade arc
e=Concavity of arc
R=Length of chord
C=Maximum thickness of blade section
B=Maximum width of blade

1. Local No. 1 plain
2. ISI standard
3. Local No. 2 serrated (Punjabi)
4. Japanese
5. Local No. 2 plain

Fig. 8.4. Pictorial describe of some sickles

## 8.3 HAND TOOLS

The hand tools are used for working in kitchen gardens, pulverising and breaking clods, opening furrows and for interculture operations.

*Materials Required* : Trench hoe, plane hoe, Gujarat hand hoe, fork hoe, garden rake, scale, tape, callipers and pan balance, etc.

*Procedure* : The five types of hand tools were examined in respect of materials of manufacture and weights were recorded. The hand tools were shown in Fig. 8.5.

*Observation* : The details of the five hand tools are presented in Table 8.3.

Table 8.3 Details of hand tools

| *Serial No.* | *Tool* | *Material* | *Weight (kg)* | *Remarks* |
|---|---|---|---|---|
| 1 | Trench hoe | Steel with wooden handle | 2·00 | Used for cutting soil and weeds, loosening soil and removal of weeds in row crops |
| 2 | Plane hoe | Steel with wooden handle | 1·50 | Used for making furrows, loosening soil and working in kitchen garden |
| 3 | Gujarat hand hoe | Steel with wooden handle | 1·25 | Opening furrows in row crops, covering of roots of groundnuts, potato, cotton and vegetables |
| 4 | Fork hoe | Steel with wooden handle | 0·95 | Used in kitchen garden |
| 5 | Garden rake | MS rod, wooden handle | 1·00 | Used for removing weeds and pebbles, etc. |

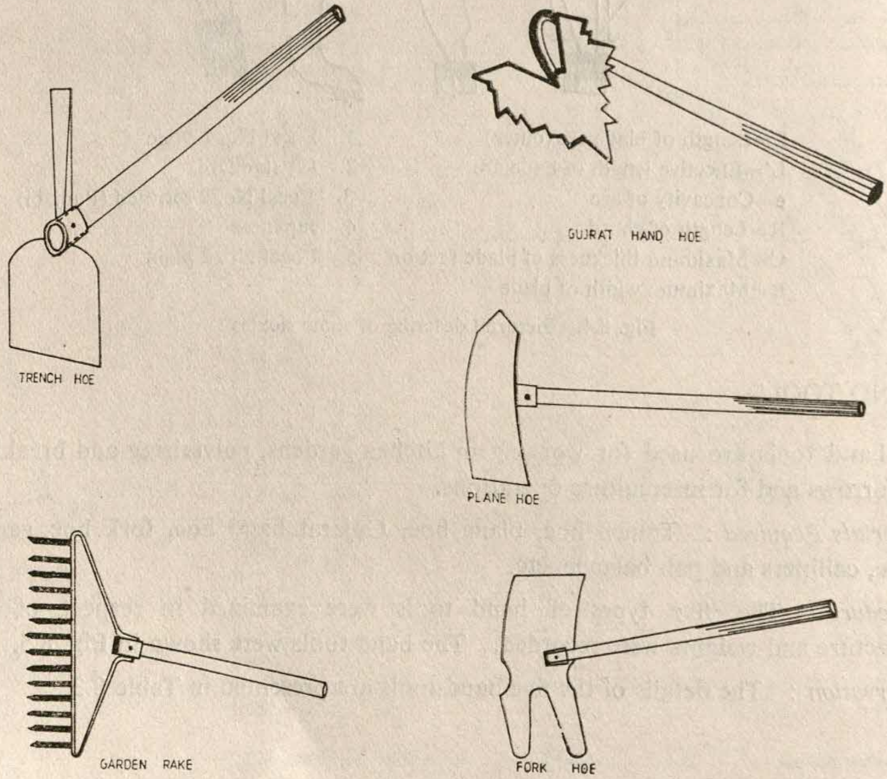


Fig. 8.5. Hand tools

# 9

# Primary Tillage Implements

## 9.1 MOULDBOARD PLOUGH

The mouldboard plough is one of the oldest agricultural implements. It is used in areas where there is sufficient rainfall and the weed growth is heavy and needs to be turned under for complete decay. It is also used to turn under the green manure crop and for mixing compost, farmyard manure and lime with the soil.

*Working Principle* : The mouldboard plough is used for cutting, lifting and turning of the furrow slice. The degree of pulverisation depends on the curvature of mouldboard. When the plough is pulled forward, the share cuts the furrow slice horizontally, the shin of mouldboard cuts furrow vertically and the soil on moving over the mouldboard is turned. To maintain the desired depth or width of cut the plough bottom is provided with vertical and horizontal clearances. The clearance between the land side (at the joining of gunnel and land side) and furrow bottom is known as down suction or vertical suction or vertical clearance and that between the land side (at the joining point of gunnel and land side) and the furrow wall is called as side suction or horizontal suction or lateral clearance. The size of a plough is expressed by the width of furrow it is designed to cut.

*Materials Required* : Mouldboard plough, scale, tape, toolbox, etc.

*Procedure* : The details of the plough bottom were studied in the light of the Fig. 9.1. It was dismantled and reassembled to get an insight to the functions and arrangement of the parts. The horizontal and vertical clearances and the size of the plough were measured.

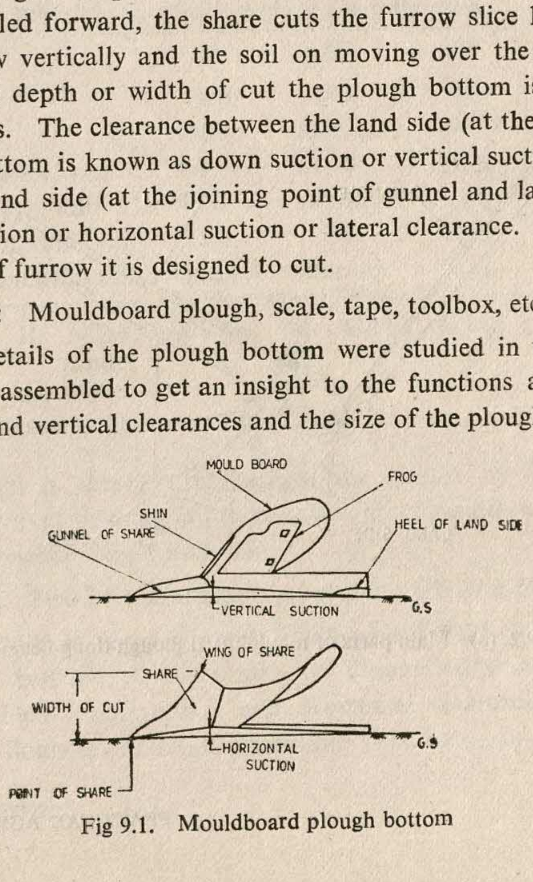


Fig 9.1. Mouldboard plough bottom

*Observation* : The clearances and size of the plough are presented in Table 9.1.

Table 9.1. Clearances and size of mouldboard plough

| *Serial No.* | *Item* | *Observed value* (mm) |
|---|---|---|
| 1 | Horizontal clearance | 5 |
| 2 | Vertical clearance | 4 |
| 3 | Plough size | 150 |

### 9.1.1 ANIMAL-DRAWN MOULDBOARD PLOUGH

The animals are the most important source of power in the farm all over the world. The bullocks and buffaloes are the principal source of animal power in Indian farms. Therefore, the animal-drawn plough is more relevant to the small and marginal farmers of the country. These ploughs are available in various sizes and trade names with different hitching arrangements.

*Materials Required* : Five animal-drawn mouldboard ploughs, scale, tape, toolbox, balance, etc.

*Procedure* : The animal-drawn mouldboard ploughs were examined. The figures of short- and long-beam type ploughs were drawn. The relevant dimensions of the ploughs were recorded.

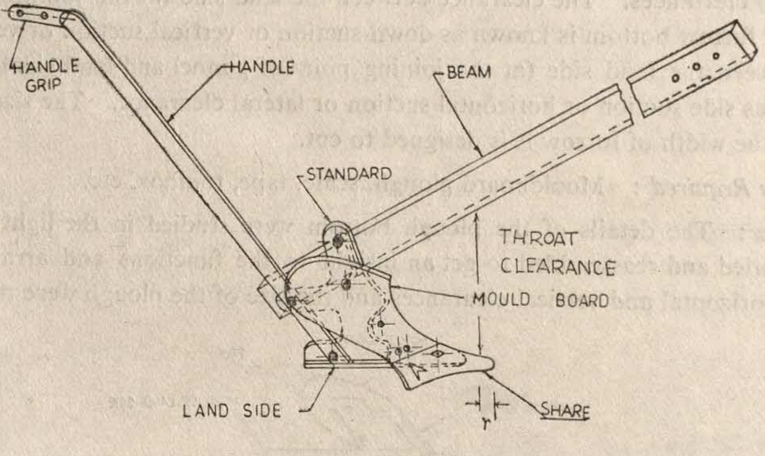


Fig. 9.2. (a) Main parts of mouldboard plough (long-beam type)

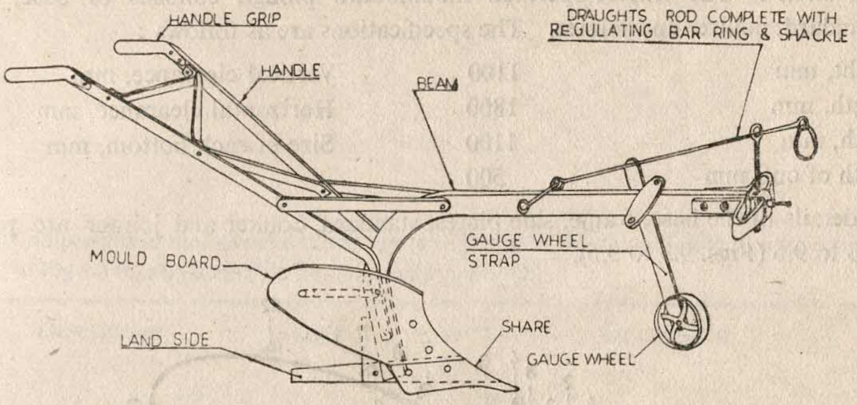


Fig. 9.2. (b) Main parts of mouldboard plough (short-beam type)

*Observation* : The informations recorded for different ploughs are presented in Table 9.2.

Table 9.2 Specifications of five different ploughs

| *Serial No.* | *Item* | *I* | *II* | *III* | *IV* | *V* |
|---|---|---|---|---|---|---|
| 1 | Weight, kg | 6·0 | 8·0 | 10·0 | 9·0 | 11·0 |
| 2 | Size, mm | 150·0 | 180·0 | 155·0 | 150·0 | 137·0 |
| 3 | Throat clearance, mm | 250·0 | 225·0 | 235·0 | 240·0 | 237·0 |
| 4 | Vertical suction, mm | 4·0 | 10·0 | 1·0 | 2·0 | 6·5 |
| 5 | Horizontal suction, mm | 8·0 | 8·0 | 2·0 | 8·0 | 4·5 |
| 6 | Material of mouldboard | Steel | Steel | Steel | Steel | Steel |

I. FIDU plough ; II. Sabash plough ; III. CAET plough ; IV. Punjab plough ; V. UPAIC plough.

### 9.1.2 TRACTOR-OPERATED MOULDBOARD PLOUGH

The mounted plough is directly attached to the tractor by three-point hitch system. During the operation it completely covers the trash or surface residue and also helps in mixing a portion of the surface residue with the top soil.

*Materials Required* : Two-bottom tractor-operated mouldboard plough, scale, tape, etc.

*Procedure* : The details of the components of the plough were studied and the parts were identified. One of the bottoms of the plough was dismantled to see the arrangement of the components and reassembled. The vertical and horizontal clearances and the size of the plough were measured. Some of the major dimensions were noted down.

*Observation* : The tractor-operated mouldboard plough consists of base, frame, side plates, standard, coulter and jointer. The specifications are as follows :

| | | | |
|---|---|---|---|
| Height, mm | 1100 | Vertical clearance, mm | 7 |
| Length, mm | 1800 | Horizontal clearance, mm | 35 |
| Width, mm | 1100 | Size of each bottom, mm | 250 |
| Width of cut, mm | 500 | | |

The details of the base, frame, side plates, standard, coulter and jointer are presented in Tables 9.3 to 9.6 (Figs. 9.3 to 9.6).

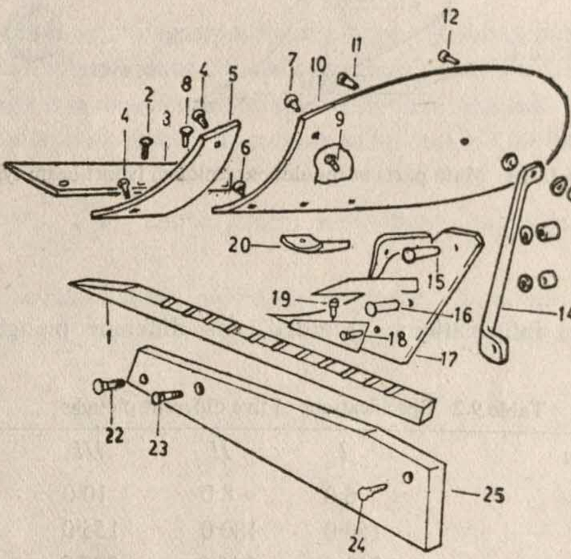


Fig. 9.3. (a) Base of a tractor-operated mouldboard plough (vide table 9.3)

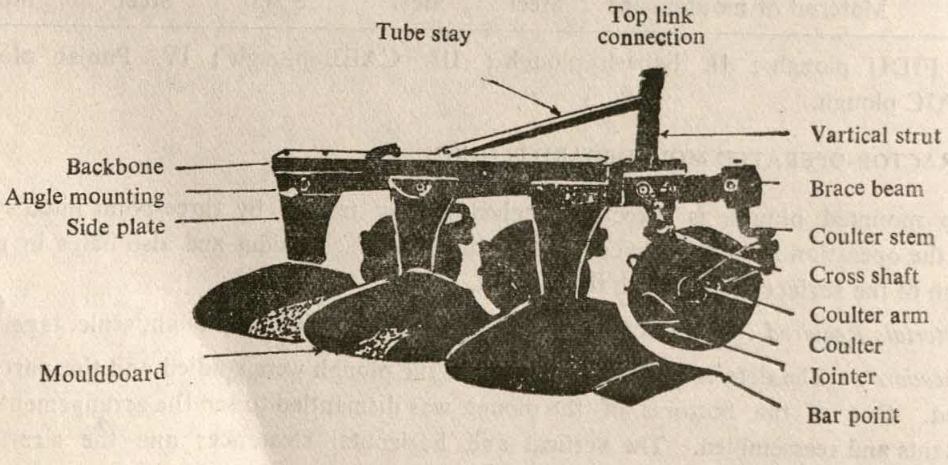


Fig. 9.3. (b) Mouldboard plough components

Table 9.3 Components of the base of a tractor-operated mouldboard plough (serial number corresponds to Fig 9.3 (b) and quantities for a two-bottom plough)

| *Serial No.* | *Description* | *Qnty* |
|---|---|---|
| 1 | Bar share | 2 nos. |
| 2 | Nuts and bolts for plough share to saddle | 4 pairs |
| 3 | Share | 2 nos. |
| 4 | Plough bolts and nuts for shim to packing piece to saddle | 4 pairs |
| 5 | Shim | 2 nos. |
| 6 | Plough bolt and nut for mouldboard to packing piece to saddle assembly | 4 pairs |
| 7 | Plough bolt and nut for mouldboard to saddle | 2 pairs |
| 8 | Nut and bolt for share to clip | 2 pairs |
| 9 | Plough bolt and nut for mouldboard to clip | 2 pairs |
| 10 | Mouldboard | 2 nos. |
| 11 | Plough bolt and nut with heavy washer for mouldboard to bracket | 2 sets |
| 12 | Plough bolt and nut with spacer and heavy washer | 4 sets |
| 13 | Bracket | 2 nos. |
| 14 | Button-head bolt with nut and lock washer for saddle to beam | 2 sets |
| 15 | Button-head bolt with nut and lock washer for saddle to beam | 2 sets |
| 16 | Saddle assembly | 2 nos. |
| 17 | Plough bolt and nut and lock washer for saddle to beam | 2 sets |
| 18 | Bar bolt with nut | 2 pairs |
| 19 | Mouldboard clip | 2 nos. |
| 20 | Plough bolt and nut for mouldboard to saddle | 2 pairs |
| 21 | Plough bolt and nut for landside to saddle assembly | 2 pairs |
| 22 | Plough bolt and nut for landside mouldboard | 2 pairs |
| 23 | Landside | 2 nos. |
| 24 | Plough bolt for landside to mouldboard | 1 pair |
| 25 | Landside | 1 nos. |

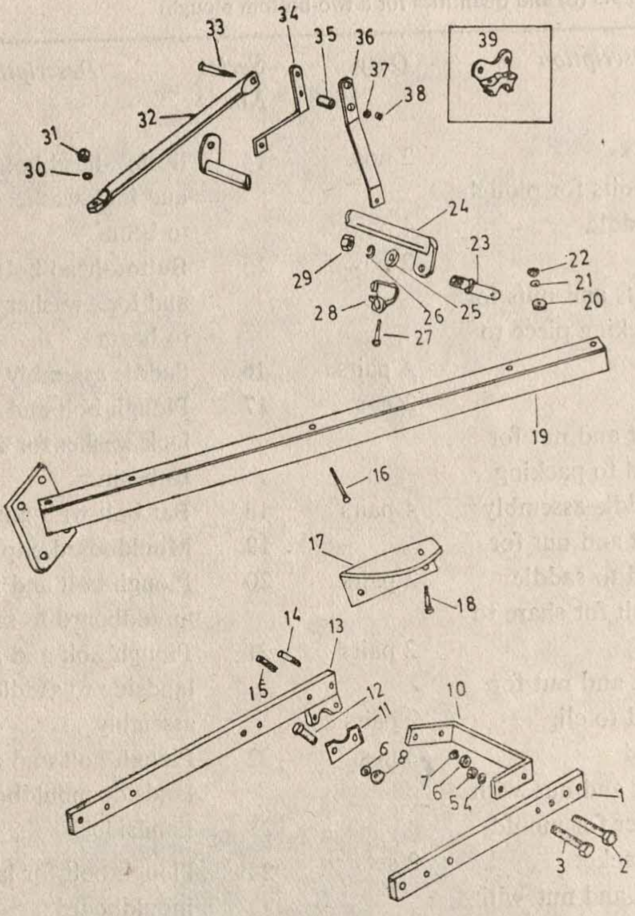


Fig. 9.4. Frame assembly of a tractor-operated mouldboard plough (vide table 9.4)

Table 9.4 Components of the frame assembly of a tractor-operated mouldboard plough (Fig 9.4 and quantities for a two-bottom plough)

| *Serial No.* | *Description* | *Qnty No.* |
|---|---|---|
| 1 | Beam | 1 |
| 2 | Right-hand front bolt nut with washer | 1 set |
| 3 | Right-hand rear bolt | 1 |
| 4 | Washer | 1 |
| 5 | Hexagonal nut | 1 |
| 6 | Hexagonal nut | 1 |
| 7 | Lock washer | 1 |
| 8 | Hexagonal nut | 2 |
| 9 | Lock washer | 2 |
| 10 | Brace (beam support) | 1 |
| 11 | Bottom bearing plate | 1 |
| 12 | Bolt | 1 |
| 13 | Second beam | 1 |
| 14 | Left-hand front bolt | 1 |
| 15 | Left-hand rear bolt, nut and washer | 1 set |
| 16 | Bolt | 1 |
| 17 | Angle mounting | 4 |
| 18 | Bolt | 3 |
| 19 | Backbone assembly | 1 |
| 20 | Special washer | 3 |
| 21 | Lock washer | 3 |
| 22 | Hexagonal nut | 3 |
| 23 | Cross-shaft pin | 2 |
| 24 | Cross-shaft assembly | 1 |
| 25 | Flat washer | 2 |
| 26 | Lock washer | 2 |
| 27 | Square-neck bolt, washer and nut | 2 sets |
| 28 | Cross-shaft cap | 1 |
| 29 | Hexagonal nut | 2 |
| 30 | Lock washer | 1 |
| 31 | Hexagonal nut | 1 |
| 32 | Tube strut assembly | 1 |
| 33 | Bolt | 1 |
| 34 | Left-hand strut | 1 |
| 35 | Spacer | 1 |
| 36 | Right-hand strut | 1 |
| 37 | Lock washer | 1 |
| 38 | Hexagonal nut | 1 |
| 39 | Cross-shaft mounting bracket | 1 |

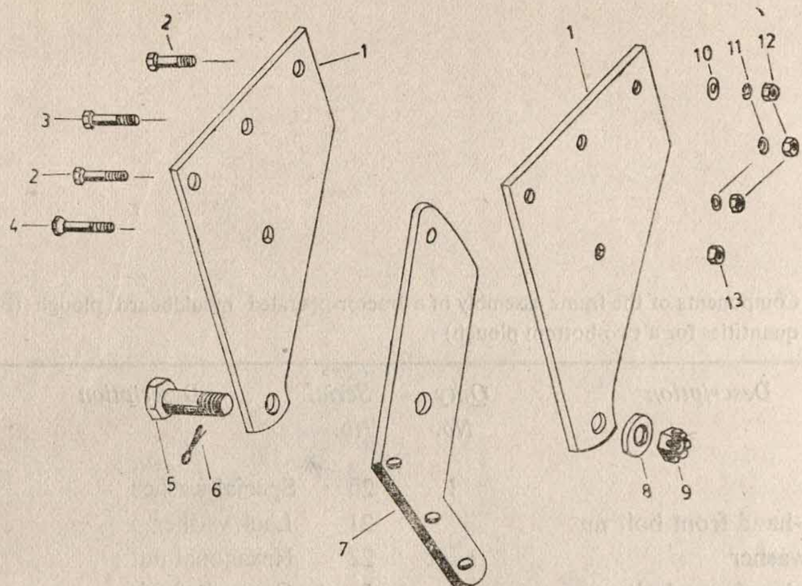


Fig. 9.5. Side plates and standard of a tractor-operated mouldboard plough (vide table 9.5)

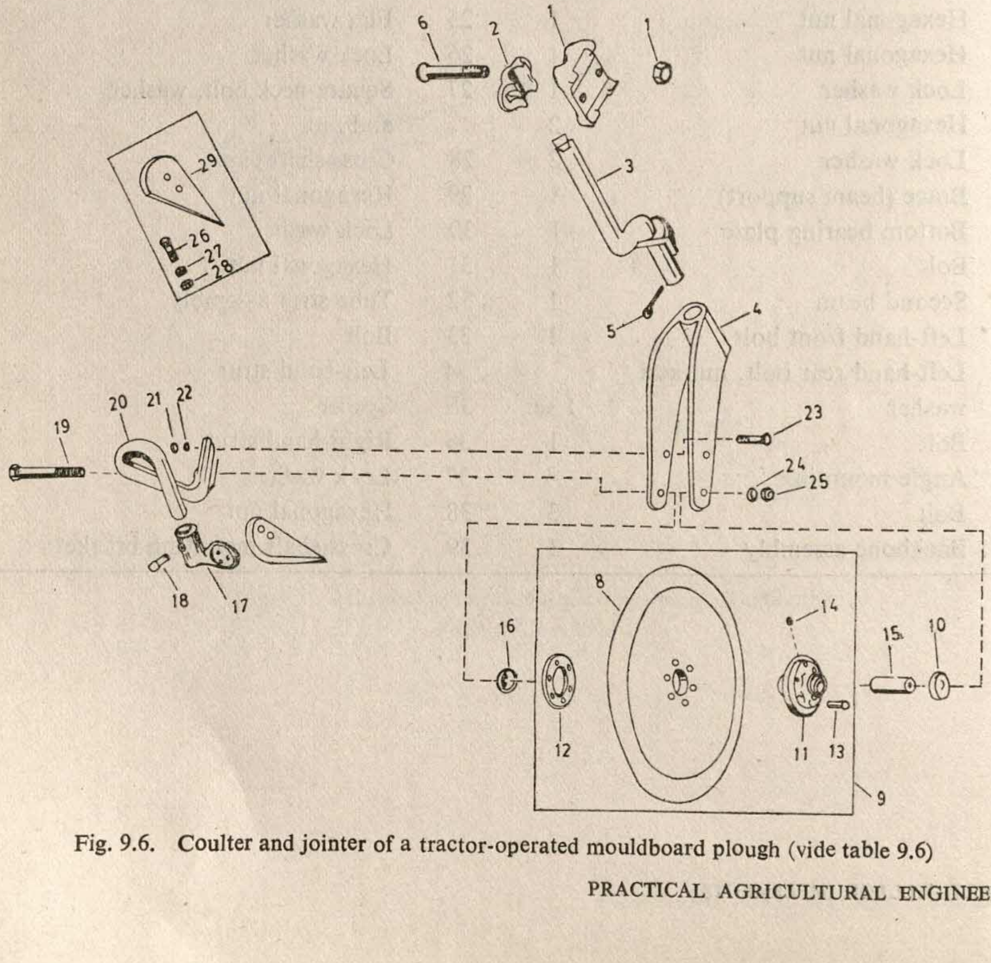


Fig. 9.6. Coulter and jointer of a tractor-operated mouldboard plough (vide table 9.6)

Table 9.5 Components of the side plate and standard of a tractor-operated mouldboard plough (Fig. 9.5 and quantities for a two-bottom plough)

| *Serial No.* | *Description* | *Qnty No.* | *Serial No.* | *Description* | *Qnty No.* |
|---|---|---|---|---|---|
| 1 | Side plate assembly | 4 | 8 | Flat washer | 2 |
| 2 | Hexagonal bolt | 4 | 9 | Slotted nut | 2 |
| 3 | Hexagonal bolt | 2 | 10 | Flat washer | 6 |
| 4 | Hexagonal shear bolt | 2 | 11 | Lock washer | 6 |
| 5 | Hexagonal special bolt | 2 | 12 | Hexagonal nut | 6 |
| 6 | Cottor pin | 2 | 13 | Hexagonal nut | 2 |
| 7 | Standard assembly | 2 | | | |

Table 9.6 Components of coulter and jointer for a tractor-operated mouldboard plough (Fig. 9.6 and quantities for a two-bottom plough)

| *Serial No.* | *Description* | *Qnty No.* | *Serial No.* | *Description* | *Qnty No.* |
|---|---|---|---|---|---|
| 1 | Coulter stem seat | 2 | 16 | Coulter hub cover | 2 |
| 2 | Coulter stem cap | 2 | 17 | Palm right hand | 2 |
| 3 | Coulter stem | 2 | 18 | Palm screw | 2 |
| 4 | Coulter fork | 2 | 19 | Hexagonal bolt | 2 |
| 5 | Cottor pin | 2 | 20 | Jointer arm | 2 |
| 6 | Square neck bolt lock washer | 4 | 21 | Hexagonal nut | 2 |
| 7 | Hexagonal nut | 4 | 22 | Lock washer | 2 |
| 8 | Coulter disc | 2 | 23 | Hexagonal bolt | 2 |
| 9 | Coulter disc and hub assembly | 2 | 24 | Lock washer | 2 |
| 10 | Coulter hub cover | 2 | 25 | Hexagonal nut | 2 |
| 11 | Coulter hub | 2 | 26 | Plough bolt | 4 |
| 12 | Coulter disc collar | 2 | 27 | Lock washer | 4 |
| 13 | Rivet | 12 | 28 | Hexagonal nut | 4 |
| 14 | Lubrication fitting | 2 | 29 | Blade | 2 |
| 15 | Coulter hub bushing | 2 | | | |

### 9.1.3 HITCHING OF A MOULDBOARD PLOUGH

*Working Principle* : The hitches are provided with the tractor and implement system for connecting the implement to the tractor. There are different types of hitches, such as

(a) Single-point hitch
(b) Three-point hitch.

The single-point hitch is the simplest method of connecting the implement to the tractor. The three-point hitch is the most common system used for attaching the mounted implements to the tractor. It consists of two lower links and one top link located behind the tractor between the two rear wheels. It checks the side thrust of the soils on the implement and provides stability. At the same time the implement is fully controlled by the operator.

*Machine/Implement Required* : One 35-h.p. tractor, tractor-drawn mouldboard plough.

*Procedure* : The attachment and detachment of the plough to the tractor were done in the following manner :

*Attachment* : 1. The top link was kept in position on the plough.

2. The tractor was moved backwards so that the tractor and plough top and lower link connections were in line.

3. The tractor engine was stopped. The operator getting down on the left-hand side, attached the left lower link of the tractor to the cross-shaft. It was secured with the linchpin.

4. The right lower link of the tractor was attached to the plough cross-shaft in above manner. The levelling lever provided on the right lower link was used during attachment of this link.

5. The operator mounted the tractor on the right side and the engine was started. The forward end of the top link was placed in the tractor top link connection. The top link pin was fixed by using the position control lever. The pin was secured with linchpin.

The levelling lever was fully wound up to reduce the slack in the check chains and to stop the implement from swinging during transport. The plough was lifted up by raising the position control lever. The tractor was moved forward to another place and the plough was placed on the ground by lowering down the position control lever.

*Detachment* : 1. Keeping the tractor in stop position and the gear in neutral, the plough was levelled by the levelling lever provided on the right lower link.

2. The plough was lowered gently by the position control lever to touch the ground.

3. The operator, seating on the tractor, moved the tractor slightly backward or forward to ease the pin and the top link were detached from the tractor end. The pin was replaced in the tractor connection and was secured with linchpin.

4. Getting down from the tractor on the right side, the right lower link was detached from the cross-shaft. The linchpin was secured in position on the right lower link.

5. The left side lower link was detached from the cross-shaft and linchpin was secured in position.

*Remarks* : The order of attachment should always be left lower link, right lower link and top link while the order of detachment should be just reverse of this. Before transporting the plough, the levelling lever of the right lower link should be screwed up fully to reduce the slackness in check chains and to prevent the swinging of the implement during transport. The linchpins should be inserted in their positions on the lower links.

### 9.1.4 FIELD ADJUSTMENT OF MOULDBOARD PLOUGH

*Theory* : To obtain the best performance from tractor-mounted mouldboard plough the following settings are to be made :

1. Cross-shaft setting—The cross-shaft is set for a nominal width of cut. The width of cut can be increased or decreased by proper cross-shaft setting.

2. Levelling—Incorrect levelling of the plough results in uneven furrows and improper turning of the soil. The implement is to be levelled with the land when seen from the rear and sides during ploughing.

3. Coulter and jointer setting—A badly set coulter or jointer causes poor work, excessive wear and increased draft.

4. Tractor and plough alignment—The proper alignment of the tractor and the plough reduce the side draft to a minimum value.

*Materials Required* : MF-1035 tractor, mouldboard plough, toolbox, tape, metre scale, etc.

*Procedure* :

*Cross-shaft setting*—The cross-shaft was adjusted to make the plough run centrally behind the tractor. This was done by setting the distance between the left-hand shoulder of the cross-shaft pin to the outside edge of the second beam at 14·6 cm ($5\frac{3}{4}''$) (Fig 9.7). This cross-shaft setting allowed the nominal width of cut, i.e., 30·5 cm (12″). The width of cut was reduced by 25 mm (1″) by rotating the cross-shaft forward by 3 mm ($\frac{1}{8}''$) from the previous setting. The width of cut was increased by 25 mm (1″) by rotating the cross-shaft rearward by 3 mm ($\frac{1}{8}''$) from the setting for nominal width of cut.

*Levelling*—The plough was levelled by setting the top link and adjusting the levelling lever. The top link was set to its standard length of 675 mm (25″). Fore and aft levelling was done by lengthening or shortening the top link. All the coulters were set at the same distance from the beam. Then the top link was adjusted until all the coulters ran at the same depth.

After adjusting the top link with the plough at working depth, the lateral levelling was done by the levelling lever provided on the right-hand side lower link of the hitch system.

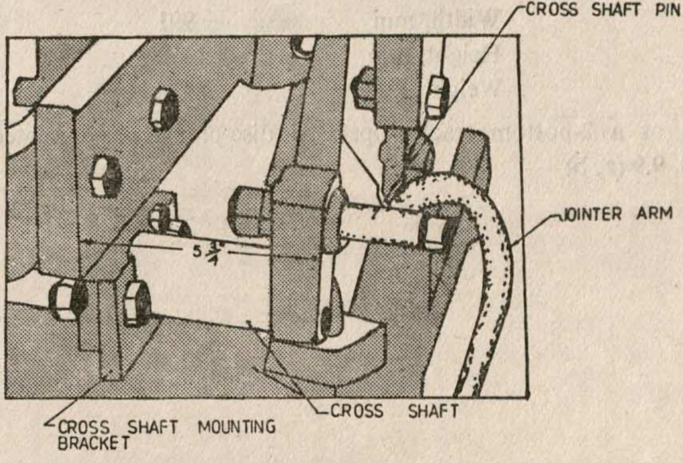


Fig. 9.7 Cross-shaft setting

*Coulter and jointer setting* : The plough was set to work. Then the rear coulter was set to give a clean cut furrow wall. The remaining coulters were matched to it. The jointers were so adjusted that the point of each jointer lightly touched the coulter blade. It was just deep enough to roll a slice of soil and trash into the bottom of the furrow.

*Depth of work* : The required depth of work was set by the draft control lever.

*Tractor and plough alignment* : Having carried all the previous settings, the slackness of the check chains on both sides were observed and made equal.

## 9.2 DISC PLOUGH

A disc plough cuts the furrow and turns it when pulled forward and is specially useful in hard, dry, trashy, stoney or stumpy land conditions. It is most useful in soils where both scouring and moisture conservation are problems.

*Working Principles* : The tractor-drawn disc plough has two or three concave steel discs of 660 mm diameter mounted on a special tubular sheet frame light in weight and of high strength. The diameter of discs may vary between 610 to 762 mm. A furrow wheel of 508 mm diameter with adjustable lead has been provided to control the width of cut. The plough is attached to the tractor by three-point hitching system. The raising and lowering of the plough is done hydraulically from the operator's seat. The furrow slices are cut by the rolling action of the discs and hardpans are not formed.

*Materials Required* : A 2-furrow disc plough, scale, tape, toolbox, platform-type weighting balance, etc.

*Procedure* : The disc plough consisted of the frame, cross-shaft and the disc bracket, the hub and scraper assembly. The various parts were dismantled, examined and listed. The general dimensions and weight were noted.

*Observation* : The general dimensions and weight of the disc plough are given below :

| | |
|---|---|
| Length, mm | 1295 |
| Width, mm | 991 |
| Height, mm | 1118 |
| Weight, kg | 236 |

The details of a 2-bottom tractor-operated disc plough are presented in Tables 9.7 and 9.8 and Figs. 9.8, 9.9 (a, b)

Table 9.7. Parts of disc plough frame and cross-shaft assembly (Fig. 9.8)

| *Ref No.* | *Description* | *Quantity, No.* |
|---|---|---|
| 1 | 2-Furrow frame | 1 |
| 2 | Pin and chain | 1 |
| 3 | Linchpin and chain | 1 |
| 4 | Cross-shaft U-bolt | 2 |
| 5 | Plate washer | 2 |
| 6 | Washer block | 2 |
| 7 | Nut | 2 |
| 8 | Beam-end cap | 1 |
| 9 | Assembly hook bolt | 1 |
| 10 | Lock washer | 1 |
| 11 | Nut | 1 |
| 12 | Plug bolt | 8 |
| 13 | Bolt (disc bracket to frame) | 2 |
| 14 | Lock washer | 2 |
| 15 | Special nut | 2 |
| 16 | Stand | 1 |
| 17 | Cross-shaft | 1 |
| 18 | Nut | 2 |
| 19 | Lock washer | 2 |
| 20 | Flat washer | 2 |
| 21 | Cross-shaft pin | 2 |

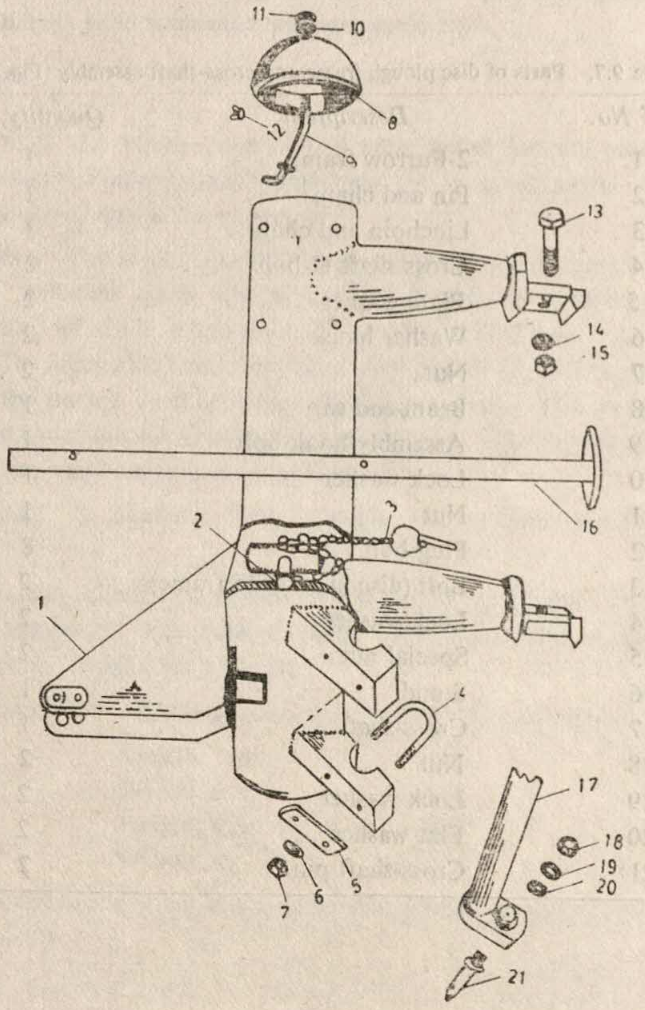


Fig. 9.8. Disc plough frame and cross-shaft assembly (vide table 9.7)

Table 9.8 Parts of disc bracket, hub and scraper assembly of disc plough (Fig. 9.9a)

| *Ref. No.* | *Description* | *Quantity, No.* |
|---|---|---|
| 1 | Bracket disc | 2 |
| 2 | Outer bearing | 2 |
| 3 | Gasket | 2 |
| 4 | Slotted nut | 2 |
| 5 | Cottor pin | 2 |
| 6 | Disc bracket cap | 2 |
| 7 | Inner bearing assembly | 2 |
| 8 | Grease retainer | 2 |
| 9 | Grease seal | 2 |
| 10 | Lubrication fitting | 2 |
| 11 | Disc hub | 2 |
| 12 | Disc | 2 |
| 13 | Bolt (disc to hub) | 10 |
| 14 | Lock washer | 10 |
| 15 | Hexagonal nut | 10 |
| 16 | Scraper assembly | 2 |
| 17 | Eye bolt | 2 |
| 18 | Scraper shank clamp | 2 |
| 19 | Scraper positioning block | 2 |
| 20 | Scraper bracket | 2 |
| 21 | Flat washer | 2 |
| 22 | Lock washer | 2 |
| 23 | Hexagonal nut | 2 |
| 24 | Carriage bolt | 2 |
| 25 | Lock washer | 2 |
| 26 | Hexagonal nut | 2 |

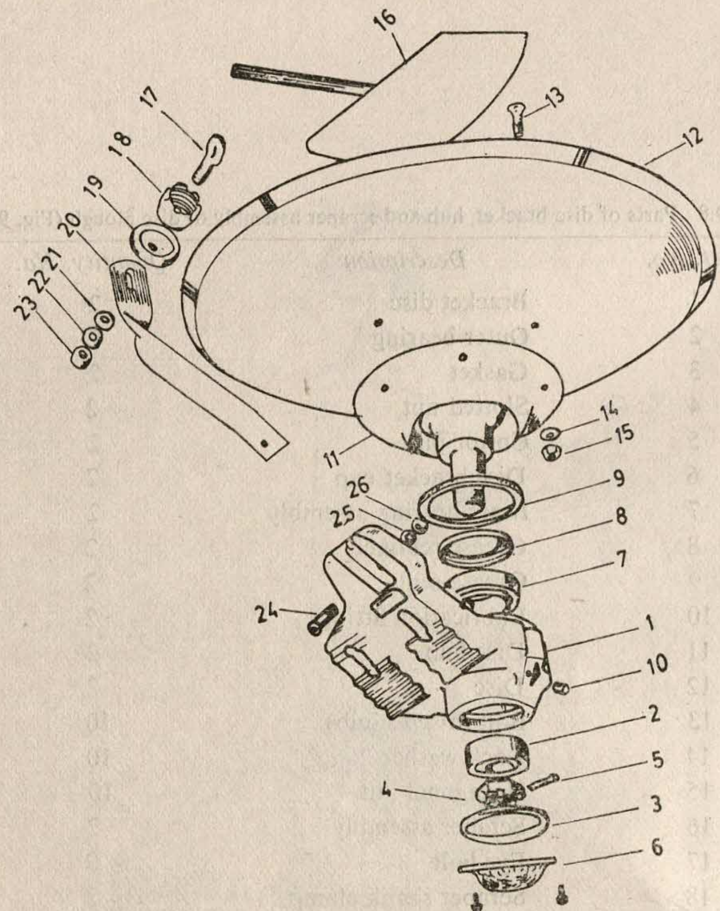


Fig. 9.9. (a) Disc bracket hub and scraper assembly of disc plough (vide table 9.8)

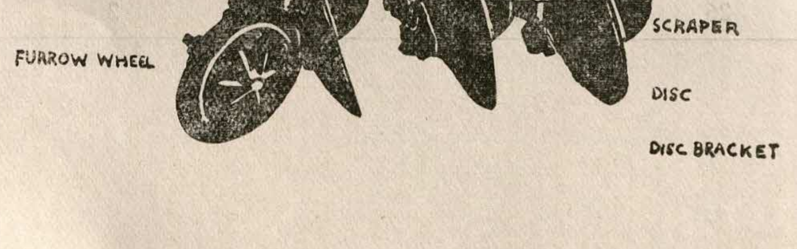


Fig. 9.9. (b) Disc plough components

### 9.2.1 MEASUREMENT OF DISC AND TILT ANGLES

A number of circular, concave and revolving steel plates is used in disc plough for cutting and inversion of the soil. The cutting angle of each disc is adjusted in both horizontal and vertical planes to suit the different ploughing conditions.

*Theory* : The angle which the plane of the disc makes with the direction of travel is known as the disc angle and that with the vertical plane is known as the tilt angle. The adjustments of these angles are needed for depth and width of cut. With reference to Fig. 9.10

$$\text{Disc angle} = \angle COB = \tan^{-1}\left(\frac{BC}{CO}\right)$$

$$\text{Tilt angle} = \angle FDE = \tan^{-1}\left(\frac{EF}{FD}\right)$$

where, *AB* and *DE* represent the plane of the disc, *OL* represents the direction of travel *DN* and *BC* represent the vertical plane.

*Materials Required* : A two-bottom disc plough, 35-h.p. tractor, bundle of thread, tape scale, pegs, spirit level, plum bob, set squares, adhesive tape, etc.

*Procedure* : The disc plough was hitched to the tractor and was taken to a level surface. The plough was grounded by using the position control lever of the hydraulic system. The two angles were measured as follows :

*Measurement of disc angle* (Fig. 9.10a) : A piece of thread dividing the disc into two equal halves was fixed diametrically as *AB* on the edge of the front disc of the plough. Another piece of thread was taken. One of its end was tied to point *O*, the mid-point of line *AB*. The other end of the thread *L* was stretched horizontally as *OL* making it parallel to the longitudinal axis of the tractor representing the direction of travel. A third piece of thread was taken and one of its ends was fixed at *B*. The other end of the third thread was stretched so as to meet the line *OL* at *C* making an angle $\angle OCB = 90°$. The lengths of all sides of the triangle *OBC* were measured.

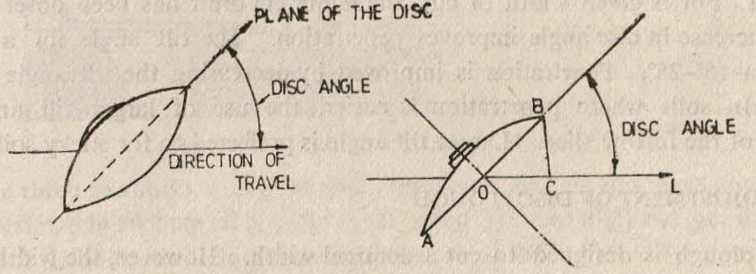


Fig. 9.10. (a) Disc angle of a disc plough

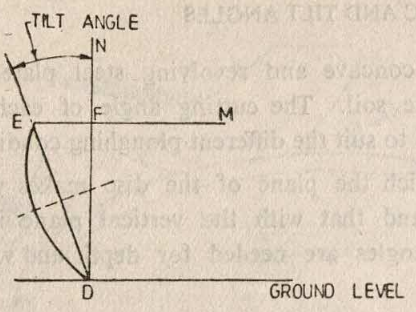


Fig. 9.10. (b) Tilt angle of a disc plough

*Measurement of tilt angle* (Fig. 9.10b) : Similar to the line *AB* of (Fig 9·10a) a piece of thread was fixed on the disc to represent the line *DE* lying on the plane of the disc periphery dividing the disc into two equal halves. A second piece of thread was taken and fixed to represent a horizontal line, *EM* lying on the vertical plane (containing the lines *DE* and *EM*). A third piece of thread (*DN*) was fixed with the help of a plum bob to represent a vertical line at *D*. The lines *EM* and *DN* cut at *F*. The point *D* was the common point on the ground plane and the lines *DE* and *DN*. The lengths of the sides of the triangle *DEF* were measured.

The same procedure was repeated to measure the disc and tilt angles of the second disc.

*Observation and Result* : The observations and results on disc and tilt angles of the disc plough are presented in Table 9.9

Table 9.9 Disc and tilt angles of disc plough

| *Serial* | *Arm* | *Front disc* | | | *Rear disc* | | |
|---|---|---|---|---|---|---|---|
| *No.* | | *Arm length* (mm) | *Disc angle* $\tan^{-1}\left(\frac{BC}{CO}\right)$ | *Tilt angle* $\tan^{-1}\left(\frac{EF}{FD}\right)$ | *Arm length* (mm) | *Disc angle* $\tan^{-1}\left(\frac{BC}{CO}\right)$ | *Tilt angle* $\tan^{-1}\left(\frac{EF}{FD}\right)$ |
| 1 | *BC* | 255 | 51° 12′ 12″ | — | 251 | 51° 27′ 6″ | — |
| 2 | *CO* | 205 | | | 200 | | |
| 3 | *EF* | 224 | — | 19° 7′ 26″ | 221 | — | |
| 4 | *FD* | 646 | | | 646 | | 18° 53′ 9″ |

*Remarks* : For a given width of cut, the minimum draft has been observed at 40°–45° disc angle. Increase in disc angle improves penetration. The tilt angle for a good plough varies between 15°–25°. Penetration is improved by decreasing the tilt angle in a standard disc plough. In soils where penetration is easier, the use of larger tilt angle results in better turning of the furrow slice. Larger tilt angle is preferred to for sticky soils.

### 9.2.2 FIELD ADJUSTMENT OF DISC PLOUGH

The disc plough is designed to cut a nominal width. However, the width of cut can be adjusted for the front disc to suit various draft and penetration conditions by adjusting the cutting angle in both vertical and horizontal planes.

*Theory* : The front furrow width is affected by (a) cross-shaft position, (b) furrow wheel adjustment and (c) steering. The adjustment of the furrow wheel spring is made to stabilize the rear of the plough, to hold it in the desired position, to prevent the side movement and to provide increased penetration in hard soils.

For nominal width of cut and to suit the different ploughing conditions, the recommended disc and tilt angles are as follows :

Table 9.10

| *Serial No.* | *Item* | *Top groove* | *Middle groove* | *Bottom groove* |
|---|---|---|---|---|
| 1 | Disc angle | 50° | 50° | 46·5° |
| 2 | Tilt angle | 22° | 18° | 15° |
| 3 | Ploughing condition | Soil that tends to break and push ahead of the disc | Average hard | Deep ploughing, heavy trash, hard and heavy soils requiring greater penetration |

For most ploughing conditions, the scrapers are set within 6·4 mm (¼″) of the outside edge of the disc with the lower point just above the disc centre.

*Materials Required* : Two-bottom disc plough, 35-h.p. tractor, toolbox, etc.

*Procedure* : The field adjustments of the disc plough were made in the following manner :

(a) *Cross-shaft position* : The position of the plough on the cross-shaft was adjusted by fixing the lateral distance *A* (Fig 9·11) between the left-hand cross-shaft carrier bracket and the left-hand shoulder on cross-shaft at 14 cm (5·5″) for 132 cm (52″) rear wheel setting. For 142 cm (56″) rear wheel setting, the distance *A* is 16·5 cm (6·5″).

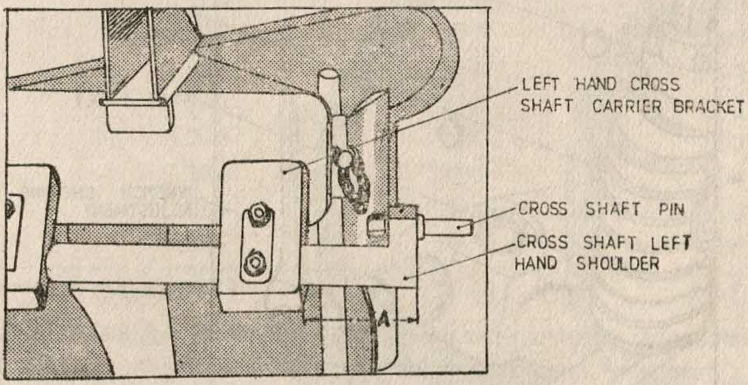

LEFT HAND CROSS SHAFT CARRIER BRACKET
CROSS SHAFT PIN
CROSS SHAFT LEFT HAND SHOULDER
A

Fig 9.11. Disc position setting on cross-shaft

There are three markings, 1, 2, 3 on the right-hand side of the cross-shaft (Fig 9.12) to provide approximately 29·8 cm (11¾″), 28 cm (11″) and 26·2 cm (10¼″) cut per disc, respectively. The cross-shaft U-bolts were loosened and the cross-shaft index line was matched with marking 2 to obtain the nominal width of cut of 28 cm (11″) for the front furrow. The U-bolts were tightened to keep the cross-shaft tightly in that position.

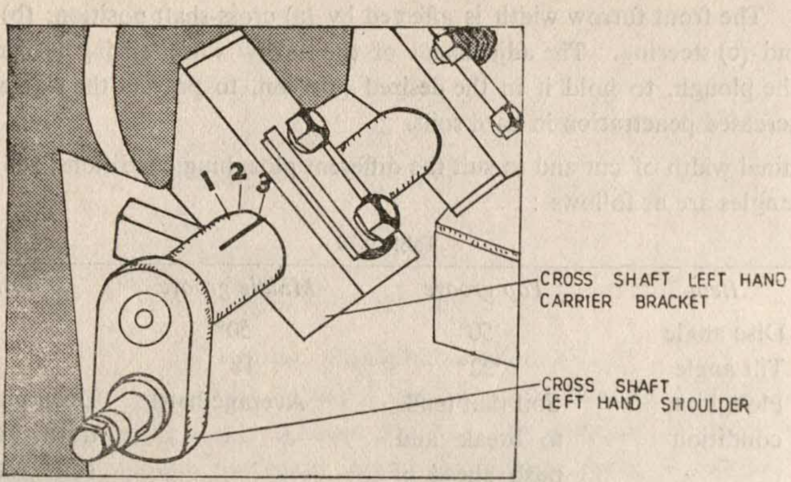

1
2
3
CROSS SHAFT LEFT HAND CARRIER BRACKET
CROSS SHAFT LEFT HAND SHOULDER

Fig 9.12. Positions on cross-shaft for setting width of cut

(b) *Furrow wheel adjustment* : The furrow wheel axle was provided with three annular grooves marked as 1, 2 and 3 (Fig 9.13). The furrow wheel axle bolt was loosened. The spindle was rotated and was set at groove 2 to match the setting 2 on the cross-shaft. The furrow wheel axle spindle had a longitudinal groove cut on its length. A lead angle of 5°

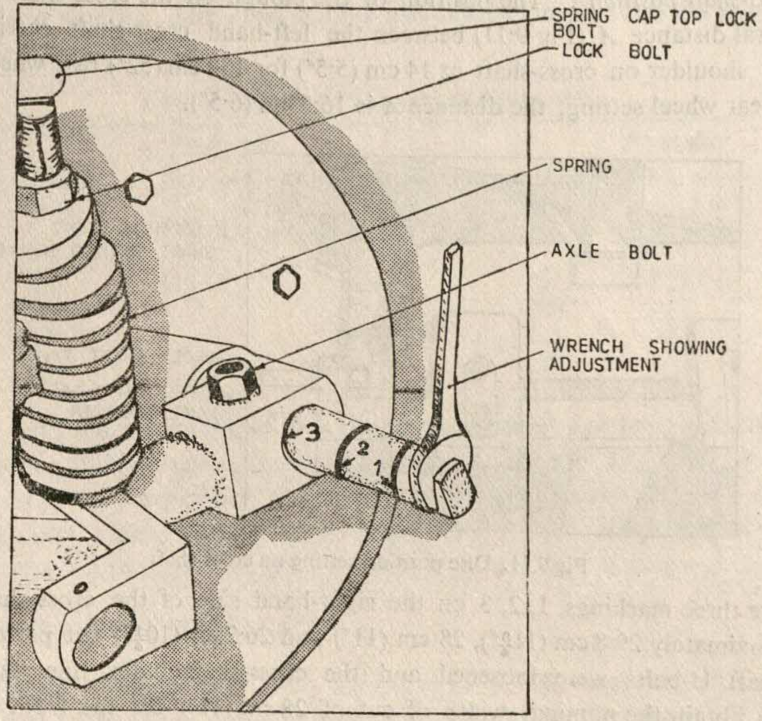


Fig 9.13. Furrow wheel adjustment

was provided by rotating the axle for satisfactory ploughing under average conditions. The axle bolt was tightened securely.

*Furrow wheel spring* : To prevent the side movement of the plough in wet soil, the lock nut was loosened and the furrow wheel spring pressure was increased by turning the lock bolt in. The plough was operated in the field and spring pressure was adjusted by trial and error till satisfactory operation was obtained. Then the lock nut was tightened in the selected position.

*Scraper adjustment* : The scraper adjustment was done by (i) raising or lowering the scraper shank in the eye bolt, (ii) locating the scraper shank in the various graduated notches and (iii) swevelling the clamp in the positioning block only for small adjustments.

The plough hitched to the 35-h.p. tractor was taken to the field. The field was ploughed and width of cut was measured at 10 different places. The procedure was repeated for cross-shaft markings 1 and 3. Widths of cut were also measured for 1 and 3 positions of the cross-shaft.

(c) *Steering* : The front furrow width was adjusted by steering to the left or right, across the furrow bottom.

*Observation* : The field observation is reported in Table 9.11

Table 9.11 Width of cut of a disc plough for different cross-shaft settings

| *Serial No.* | *Width of cut at different cross-shaft settings*, cm | | |
|---|---|---|---|
| | *1* | *2* | *3* |
| 1 | 29·5 | 28·5 | 26·1 |
| 2 | 29·8 | 27·9 | 26·6 |
| 3 | 29·2 | 27·6 | 25·7 |
| 4 | 30·1 | 27·7 | 25·9 |
| 5 | 30·5 | 28·4 | 26·2 |
| 6 | 29·1 | 28·1 | 25·5 |
| 7 | 29·9 | 28·0 | 26·3 |
| 8 | 30·4 | 27·8 | 26·4 |
| 9 | 29·6 | 28·2 | 25·9 |
| 10 | 29·7 | 28·3 | 25·6 |
| Average | 29·78 | 28·05 | 26·18 |

*Remarks* : In loose soil the furrow wheel spring pressure is to be increased as described above. For hard soil, the pressure on the spring is to be reduced by adjusting the lock nut and bolt to provide increased penetration.

The position of the check strut, ploughing depth, steering position, levelling of the plough with the line of travel and land, forward speed, addition of weight on the plough and tractor, etc., are to be kept in mind for best performance.

# 10

# Secondary Tillage Implements

## 10.1 ANIMAL-DRAWN DISC HARROW

The disc harrow is used for cutting and covering the soil effectively. It also pulverises the soil, leaves a surface mulch and compacts the subsurface.

*Materials Required* : Animal-drawn disc harrow, scale, tape, toolbox, etc.

*Procedure* : The different parts of the animal-drawn disc harrow consisting of discs, tool bar, seat and hitch, etc., were studied. The tilt angle, gang angle, disc diameter and concavity, spacing between discs and width of cut were measured.

*Observation* : The arrangement of the components of the disc harrow is shown in Fig. 10.1. It has four discs. It is a single-action harrow with two gangs, each gang having two discs. The discs have been fixed with PVC bush bearing in wooden housing. The other observations are reported below :

| | |
|---|---|
| Tilt angle | 4°45′ |
| Gang angle | 27°22′ |
| Disc diameter, mm | 480 |
| Concavity, mm | 41 |
| Spacing between discs, mm | 150 |
| Width of cut, mm | 450 |

*Remarks* : The animal-drawn disc harrow is also used by farmers for clod crushing and puddling.

## 10.2 TRACTOR-OPERATED OFFSET DISC HARROW

The disc harrow is second only to the mouldboard plough in its importance as tillage implement. Heavy duty disc harrows are used to destroy weeds, to cut and mix up stubbles. It is also used as primary tillage implement in orchards and open fields.

*Materials Required* : Offset disc harrow, 35-h.p. tractor, tape, scale, thread, etc.

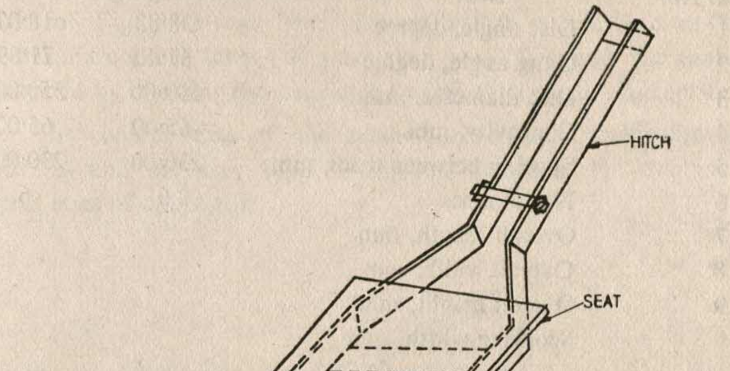


Fig. 10.1. Animal-drawn disc harrow

*Procedure* : The different parts of the tractor-operated offset disc harrow were studied with respect to individual disc, number of disc per gang and gang arrangement, etc. The disc angle, gang angle, diameter of disc, concavity, spacing between discs, width of cut and ground clearance, etc., were measured.

*Observation* : There are two gangs in the offset disc harrow with six discs in each gang. The frame is made of steel. The rear part of the frame is attached to the bearings of the disc gangs. A lever has been fixed above the frame to regulate the gang angle. The discs are also made of steel. The discs are mounted on arbor bolts and are held apart on the bolt by spacer spools. The discs, spools and bolts revolve as one unit. The various measurements taken on the disc harrow are given below :

| *Serial No.* | *Item* | *Front gang* | *Rear gang* | |
|---|---|---|---|---|
| 1 | Disc angle, degree | 28·82 | 18·07 | |
| 2 | Gang angle, degree | 67·40 | 71·89 | |
| 3 | Disc diameter, mm | 550·00 | 550·00 | |
| 4 | Concavity, mm | 65·00 | 65·00 | |
| 5 | Spacing between discs, mm | 230·00 | 230·00 | |
| 6 | No. of discs | 6 | 6 | |
| 7 | Overall length, mm | | | 2000 |
| 8 | Overall width, mm | | | 1480 |
| 9 | Overall height, mm | | | 1235 |
| 10 | Working width, mm | | | 1420 |

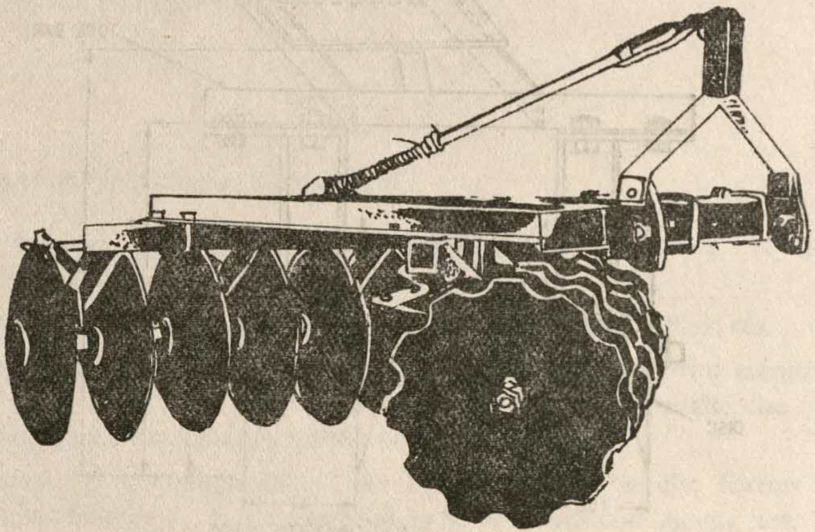


Fig. 10.2. Tractor-operated offset disc harrow

*Remarks* : The offset disc harrow can be made to work to the right or left of the tractor thereby working close to the trunks of trees below overhanging branches in orchards.

## 10.3 TRACTOR-OPERATED CULTIVATOR

A cultivator is used to stir the surface soil to a shallow depth in between the rows of the young plants for destroying the young weeds and promoting plant growth. This is also used to control the weeds by stirring the soil on the seed bed before planting. The other uses of the cultivator are opening the land, preparing the seedbed, and sowing the seeds and fertilizer. The seed and fertilizer are sown by fitting a suitable seeding attachment to the cultivator.

*Materials Required* : 35-h.p. tractor, tractor-mounted nine-tyne spring type cultivator, tape, scale, etc.

*Procedure* : The cultivator consisting of shovels, tynes, frame or tool bar, etc., was studied in the light of Figs. 10.3 and 10.4. The cultivator was hitched to the tractor and lifted up by the hydraulic control lever. It was taken to a field and the usefulness of the spring was demonstrated by allowing the cultivator to pass through an obstruction.

*Observation* : The components of the spring-loaded 9-tyne cultivator are presented in Figs. 10.3 and 10.4 and in Table 10.1. Table 10.2 illustrates the drawbar horse power required for different sizes of cultivators.

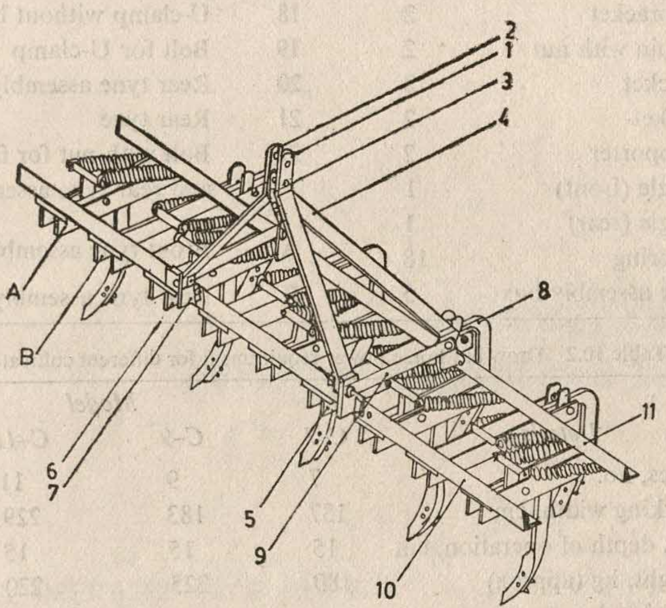


Fig. 10.3. Tractor-mounted nine-tyne cultivator with spring-loaded tyne (vide table 10.1)

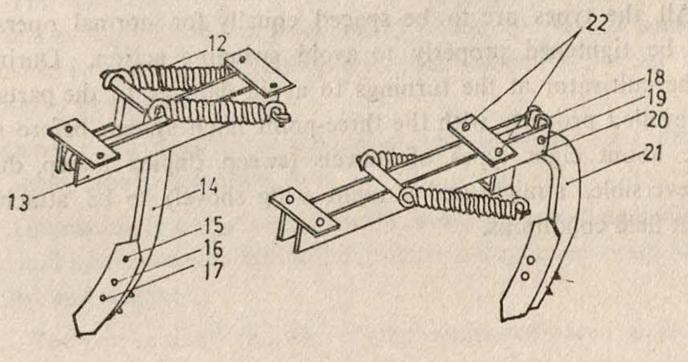


Fig. 10.4. Front and rear tyne assembly of a cultivator displayed in Fig. 10.3

Table 10.1 Details of spring-loaded 9-tyne cultivator (vide Figs. 10.3 and 10.4)

| *Serial No.* | *Item* | *Qnty No.* | *Serial No.* | *Item* | *Qnty No.* |
|---|---|---|---|---|---|
| 1 | Top link pin | 1 | 14 | Front tyne | 5 |
| 2 | Mild steel bush | 1 | 15 | Reversible shovel | 9 |
| 3 | Mild steel bolt and nut | 1 set | 16 | Carriage bolt with nut | 9 |
| 4 | Top link bracket supporter | 2 | 17 | Carriage bolt with nut | 9 |
| 5 | Top link bracket | 2 | 18 | U-clamp without bolt | 9 |
| 6 | Side link pin with nut | 2 | 19 | Bolt for U-clamp | 18 |
| 7 | Front bracket | 2 | 20 | Rear tyne assembly box | 2 |
| 8 | Rear bracket | 2 | 21 | Rear tyne | 4 |
| 9 | Frame supporter | 2 | 22 | Bolt with nut for fitting front and rear tyne assembly | 36 |
| 10 | Frame angle (front) | 1 | | | |
| 11 | Frame angle (rear) | 1 | | | |
| 12 | Tension spring | 18 | A | Front tyne assembly | 5 |
| 13 | Front tyne assembly box | 5 | B | Rear tyne assembly | 4 |

Table 10.2 Draw bar horse power requirement for different cultivators

| *Serial No.* | *Details* | *Model* | | | |
|---|---|---|---|---|---|
| | | *C–7* | *C–9* | *C–11* | *C–13* |
| 1 | Tynes, no. | 7 | 9 | 11 | 13 |
| 2 | Working width, cm | 137 | 183 | 229 | 275 |
| 3 | Max depth of operation, cm | 15 | 15 | 15 | 15 |
| 4 | Weight, kg (approx) | 180 | 225 | 220 | 345 |
| 5 | Drawbar h.p. required (approx) | 15–20 | 20–30 | 30–40 | above 40 |

*Remarks* : All the tynes are to be spaced equally for normal operation. The nuts and bolts are to be tightened properly to avoid swinging action. During operation it is essential to lift the cultivator at the turnings to avoid damage to the parts. The cultivator is required to be levelled properly with the three-point hitch system before starting the field-work. There are about eight types of shovels (sweep, duplex sweep, duplex half sweep, blade, twisted, reversible, straight and straight wing shovel) to be attached to the tynes to suit the different field conditions.

# 11

# Seeding, Planting and Fertilizer-Application Equipments

## 11.1 MANUALLY OPERATED SEED DRILL

A wide variety of crops are grown in the country each having its own sowing requirements for best growth. The seed rate, the spacing of hills in a line, spacing between lines, depth of placement and compaction are some of the factors which need careful consideration. When the seed drill is pushed forward, the furrow opener opens the furrow, seeds are dropped into the furrow and covered by the soil.

*Materials Required* : Manually operated single- and three-row seed drills, platform-type weighing balance, scale, tape and toolbox, etc.

*Procedure* : The manually operated single-row and three-row seed drills were dismantled. The different parts and systems were identified and their arrangements were observed. The seed drills were assembled and weighed.

*Observation* : The row spacing in case of the single-row seed drill is required to be adjusted as per requirement of the crop by setting the marker whereas that of the three-row seed drill is found to be 100 mm. The seed metering in case of single-row seed drill is done by a fluted roller mechanism whereas that in case of three-row seed drill is obtained through wooden rollers with grooves. The weights of the single- and three-row seed drills are noted to be 8 and 12 kg, respectively. The details of the two seed drills are shown in Figs. 11.1 and 11.2.

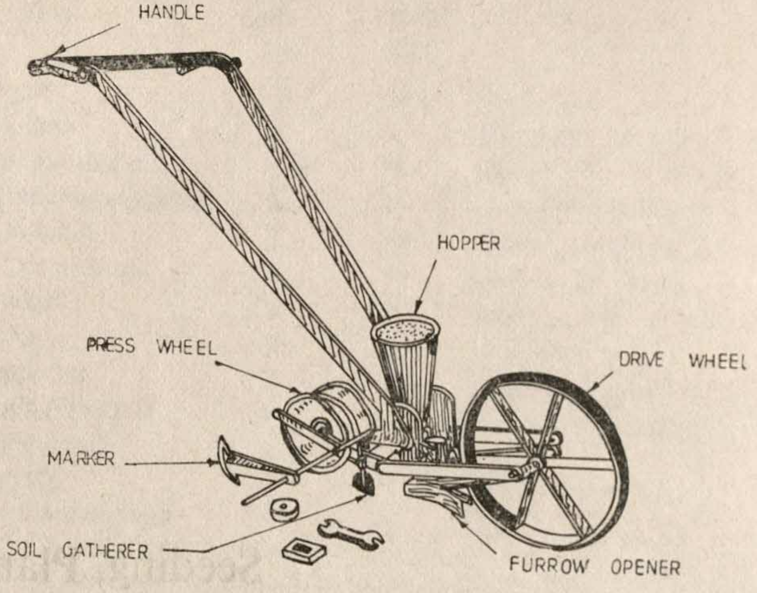


Fig. 11.1. Single-row seed drill

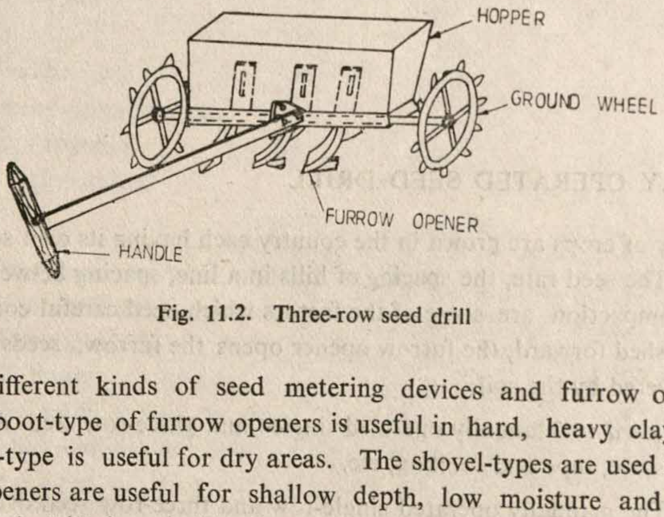


Fig. 11.2. Three-row seed drill

*Remarks* : Different kinds of seed metering devices and furrow openers are used on seed drills. The boot-type of furrow openers is useful in hard, heavy clay and black soils whereas the knife-type is useful for dry areas. The shovel-types are used in lighter soils and disc-type furrow openers are useful for shallow depth, low moisture and trash conditions. The single-row seed drill is suitable for sowing jute, mustard, linseed, paddy and wheat. Three-row seed drill is used for upland paddy as well as wheat.

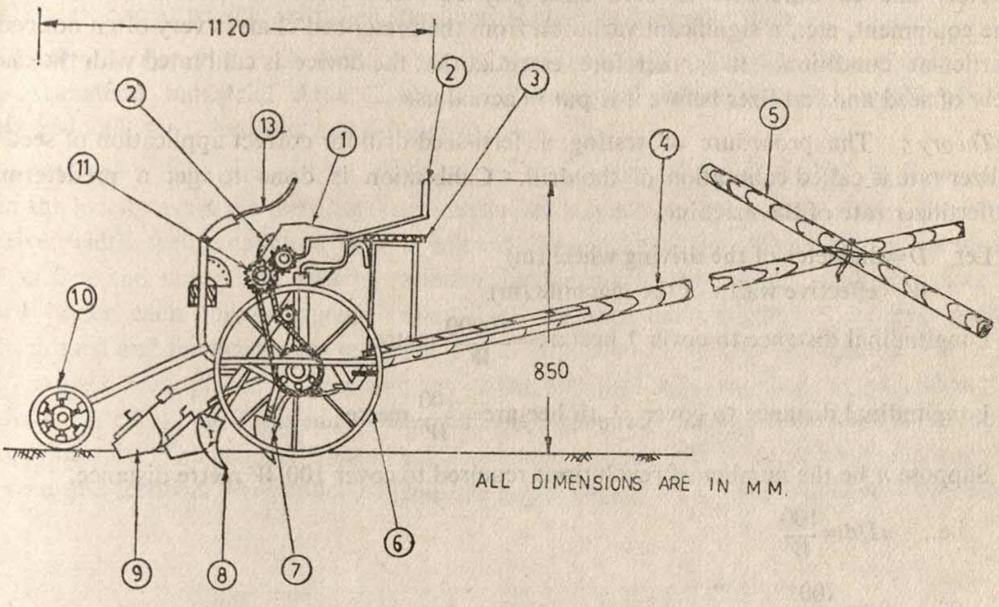
## 11.2 ANIMAL-DRAWN SEED DRILL

A three- to five-row seed drill having a working width of about 1 m is an ideal size for animal draft. As the numbers of rows in an animal-drawn seed drill are many, the sowing operation is done quicker before the soil moisture gets depleted.

*Materials Required* : TNAU cup-feed-type seed drill, tape, scale, toolbox, platform-type weighing balance, etc.

*Procedure* : The components of the TNAU (Tamil Nadu Agricultural University) cup-feed-type seed drill were identified. The seed drill was dismantled and reassembled to study the arrangement of different parts and systems. The seed drill was weighed.

*Observation* : The details of the seed drill are presented in Fig. 11.3. The tynes are attached with furrow openers and furrow closers. The furrow openers and closers are of shoe type. A seat has been provided for the operator. The specifications are noted as follows :



1. **Seed box**
2. **Seed cut-off lever**
3. **Operators**
4. **Beam**
5. **Yoke**
6. **Ground wheel**
7. **Seed tube**
8. Furrow
9. Furrow closer
10. Compaction wheel
11. Gear transmission system
12. Seed disc
13. Tyne-lifting handle

Fig. 11.3. Animal-drawn seed drill

| | |
|---|---|
| No. of rows | Three |
| Metering mechanism | Cup-feed-type |
| Length, mm | 1120 |
| Width, mm | 850 |
| Height, mm | 850 |
| Row spacing, mm | 300 |
| Weight, kg | 90 |

*Remarks* : This seed drill is used for sowing sorghum, maize, pulses, groundnut and cotton. Its field capacity is about 0·12 ha/hr.

### 11.2.1 CALIBRATION OF A FERTI-SEED DRILL

The seed-cum-fertilizer drills are designed to work at a desired application rate of the seed and fertilizer. A calibration chart is, therefore, provided by the manufacturer. However, due to difference in seed size, physical condition of the fertilizer, wear and tear of the equipment, etc., a significant variation from the prescribed chart is very often noticed for a particular condition. It is, therefore, essential that the device is calibrated with the chosen variety of seed and fertilizer before it is put in actual use.

*Theory* : The procedure of testing a ferti-seed drill for correct application of seed and fertilizer rate is called calibration of the drill. Calibration is done to get a predetermined seed/fertilizer rate of the machine.

Let $D$=diameter of the driving wheel (m)

$W$=effective width of the machine (m)

Longitudinal distance to cover 1 hectare$=\frac{10000}{W}$ metre

Longitudinal distance to cover $\frac{1}{100}$th hectare$=\frac{100}{W}$ metre

Suppose $n$ be the number of revolutions required to cover $100/W$ metre distance.

i.e., $\pi Dn=\frac{100}{W}$

or $$n=\frac{100}{\pi DW} \tag{11.1}$$

The machine is to be raised so that the drive wheel becomes free to rotate. A paper or canvas or a cloth piece may be placed below the wheel. A chalk mark may be put on the rim as well as on the frame of the drill for counting the number of revolutions. The seed/fertilizer may be placed in the hopper. The wheel may be put on rotation and be continued till it completes $n$ revolutions. The dropped seed/fertilizer may now be collected and weighed (M kg).

$$\therefore \text{ Theoretical application rate}=100 \text{ M kg/ha} \tag{11.2}$$

Assuming $P$ percentage loss due to slippage, turning, etc.

$$\text{Application rate}=(100-P) \text{ M kg/ha} \tag{11.3}$$

The lever provided for adjusting the seed flow may be changed and the same process be repeated until desired rate is obtained.

The fertilizer required to be applied on the basis of crop and soil is generally recommended as a ratio of nitrogen (N), phosphorus (P) and potash (K) in kilogram per hectare. Depending on the quality of the commercially available fertilizer the actual weights of the fertilizers to satisfy the need of N, P, K are to be calculated as follows :

Let $F_1$, $F_2$ and $F_3$ be the three types of available fertilizers containting $x$, $y$ and $z$ percentage of N, P and K, respectively, and the prescribed dose be N : P : K per hectare. Then $\frac{100}{x}$ (N) kg of $F_1$ ; $\frac{100}{y}$ (P) kg of $F_2$ and $\frac{100}{z}$ (K) kg of $F_3$ are to be applied in one hectare of land.

Half of nitrogenous fertilizer and full dose of phosphorous and potassic fertilizer are applied as basal dose, during sowing. Balance nitrogenous fertilizer is to be applied in two equal doses, one at panicle initiation stage and another at flowering stage.

*Materials Required* : A bullock-drawn ferti-seed drill (Swastik Manufacturers Ltd., 13/1 Azamabad Industrial Area, Hyderabad), scale, tape, chalk, toolbox, weighing balance, wooden blocks, seed, fertilizer and 6 paper bags.

*Procedure* : The amount of fertilizer to be applied on the basis of N, P, K percentage (from the locally available fertilizers) and prescribed doses were estimated. The diameter and effective width were measured and $n$ was calculated (Eq. 11.1). The drill was set on a flat level surface and was raised placing wooden blocks under the frame. A cloth piece was placed under each furrow opener (three each for seed and fertilizer). The lever positions for both seed and fertilizer were selected (Figs. 11.4 and 11.5) and set appropriately. The seed/fertilizer was placed in the hopper (half-full) and was supplied as and when it was required. A chalk mark was put on the rim of the drive wheel and on the frame for counting the revolutions. The ground-drive wheel was then rotated till it completed $n$ revolutions. The seed and fertilizer were collected from the paper bags placed below each tyne and weighed.

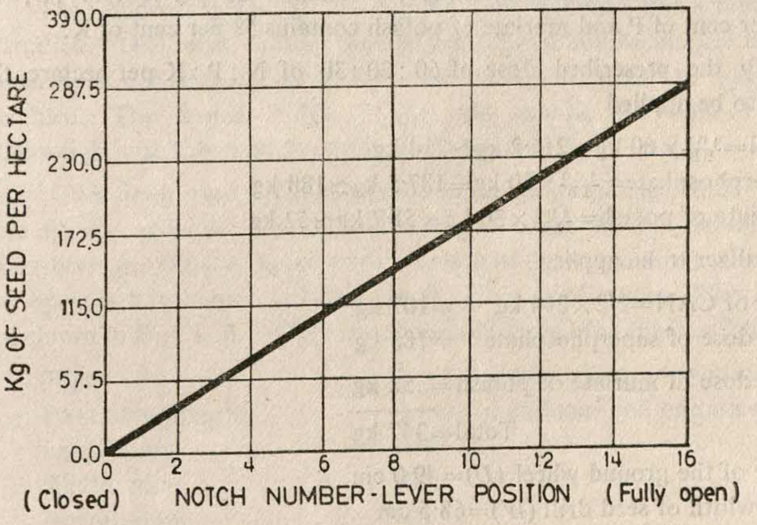


Fig. 11.4. Approximate calibration curve for small grain
( given by the manufacturer )

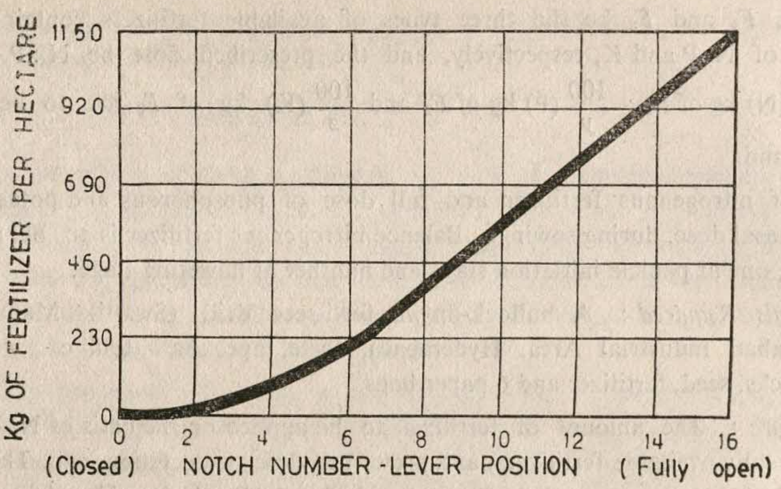


Fig. 11.5. Approximate calibration curve for fertilizer
( given by the manufacturer )

*Observation* :

| | |
|---|---|
| Variety of paddy to be sown | D 92 (Subhadra) |
| Soil type | Laterite |
| Recommended seed rate | 75 kg/ha |
| Recommended dose of N : P : K per hectare | 60 : 30 : 30 |

Commercially available fertilizer (CAN) contains 28 per cent of N ; superphosphate contains 16 per cent of P and muriate of potash contains 58 per cent of K.

To satisfy the prescribed dose of 60 : 30 : 30 of N : P : K per hectare, the quantities of fertilizers are to be applied

$$\text{CAN}=\tfrac{100}{28}\times 60\text{ kg}=214{\cdot}2\text{ kg}\simeq 214\text{ kg}$$

$$\text{Superphosphate}=\tfrac{100}{16}\times 30\text{ kg}=187{\cdot}5\text{ kg}\simeq 188\text{ kg}$$

$$\text{Muriate of potash}=\tfrac{100}{58}\times 30\text{ kg}=51{\cdot}7\text{ kg}\simeq 52\text{ kg}$$

Total fertilizer to be applied

Half of CAN=1/2×214 kg =107 kg
Full dose of superphosphate =188 kg
Full dose of muriate of potash = 52 kg
Total=347 kg

Diameter of the ground wheel $(D)=49{\cdot}0$ cm
Effective width of seed drill $(W)=68{\cdot}5$ cm

$$\therefore \quad n=\frac{100}{\pi DW}=\frac{100}{\pi(0{\cdot}49)(0{\cdot}685)}=94{\cdot}8$$

$$\simeq \text{ 95 revolutions (say)}$$

Table 11.1 Seed and fertilizer dropped by ferti-seed drill

| *Serial No* | *Furrow* | *Seed dropped* (gm) | *Fertilizer dropped* (gm) |
|---|---|---|---|
| 1 | Left hand | 280·0 | 1320·0 |
| 2 | Middle | 290·0 | 1295·0 |
| 3 | Right hand | 275·0 | 1335·0 |
| Total | | 845·0 | 3950·0 |

It is presumed that percentage loss due to slippage, turning, etc., is 11 per cent (approx).

$\therefore$ Application rate of seed $= 100\,(1-0{\cdot}11)(0{\cdot}845)$ kg/ha

$= 75{\cdot}21$ kg/ha

Application rate of fertilizer $= 100(1-0{\cdot}11)(3{\cdot}95)$ kg/ha

$= 351{\cdot}55$ kg/ha

*Remarks* : The rated doses are very close to the prescribed doses. Hence, it may be accepted.

## 11.3 JYOTI PLANTER

This planter has been developed by the Farm Implement and Machinery Scheme, College of Agriculture, Mahatma Phule Krishi Vidyapeeth, Pune. It is used for planting seeds and drilling of fertilizer.

*Materials Required* : Jyoti planter, scale, tape, toolbox, platform-type weighing balance, etc.

*Procedure* : The different parts of the planter were identified and arrangements of the systems were studied. One unit of the planter was dismantled to see the arrangement of hopper, seed-metering mechanism, cut-off device, seed delivery tube, furrow opener, etc. The unit was reassembled. The length, width, height, row spacing and width of coverage were measured and the weight was taken on the weighing balance.

*Observation* : This is a seed planter-cum-fertilizer drill having three separate seed hoppers for three furrow openers. The seed metering is achieved by vertical seed plates. A dog clutch has been provided to prevent the planting of seeds and fertilizer during turning. Separate furrow openers have been provided for fertilizer application. The details of the planter has been shown in Fig. 11.6. The general specifications are found as follows :

| | |
|---|---|
| Type | Animal-drawn, three-row vertical plate |
| Power requirement | A pair of bullocks and one person |
| Length, mm | 3600 |
| Width, mm | 1620 |
| Height, mm | 700 |
| Row spacing, mm | 450 |
| Width of coverage, mm | 1350 |
| Weight, kg | 80 |

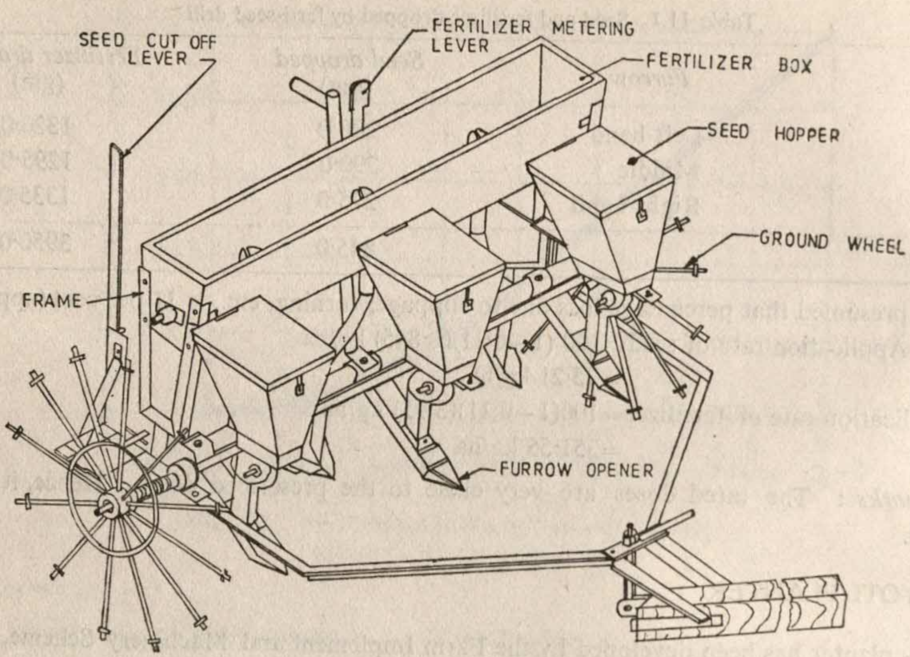


Fig. 11.6. Jyoti planter

*Remark* : The Jyoti planter is suitable for groundnut, maize and sorghum. The field capacity is about 1 hectare per day.

## 11.4 TRACTOR-OPERATED SEED DRILL

A tractor-operated seed drill consists of a seeding attachment which is used with a cultivator to sow seed in rows.

*Working Principle* : The hopper is made of steel and is secured to the cultivator at four points. There are 9 holes in the base of the hopper through which the seeds fall via flexible tubes to a special boot fitted to each tyne. The holes on the base of the seed hopper are closed when the cultivator is raised by the hydraulic system during turning at the end of the rows. The number of rows can be changed by closing the holes on the base of the hopper to achieve different row spacings. Recommended row spacings and wheel settings are given in Table 11.2.

Table 11.2 Recommended wheel setting for tractor-operated seed drill

| *Serial No.* | *Row spacing* (inch) | *No. of rows* | *Required wheel setting* (inch) | *Available wheel setting* (inch) | *Remarks* |
|---|---|---|---|---|---|
| 1 | 7 | 9 | 63 | 64 | Possible |
| 2 | 7 | 8 | 56 | 56 | Not possible |
| 3 | 8 | 9 | 72 | 72 | Possible |
| 4 | 8 | 8 | 64 | 64 | Not possible |
| 5 | 9 | 9 | 81 | 80 | Possible |
| 6 | 9 | 8 | 72 | 72 | Not possible |
| 7 | 9 | 7 | 63 | 64 | Possible |
| 8 | 10 | 7 | 70 | 68 or 72 | Possible |
| 9 | 11 | 7 | 77 | 76 | Possible |
| 10 | 12 | 6 | 72 | 72 | Not possible |
| 11 | 12 | 5 | 60 | 60 | Possible |
| 12 | 14 | 5 | 70 | 68 or 70 | Possible |
| 13 | 14 | 4 | 56 | 56 | Possible |

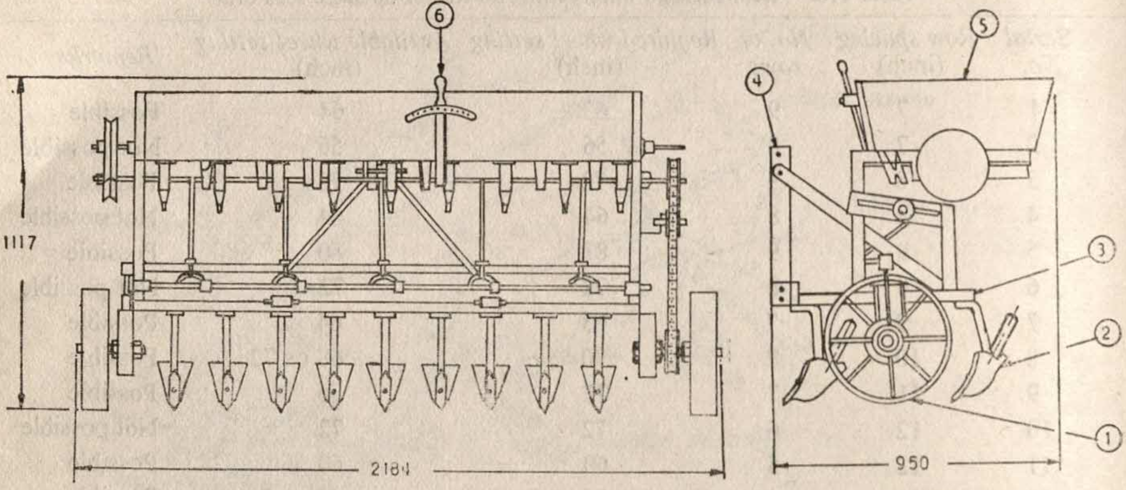
*Materials Required* : MF-1035 tractor, 9-tyne cultivator with seeding attachment, toolbox, scale, tape, 10 kg of seeds, etc.

*Procedure* : The different components of the seed drill were identified and their arrangement was studied. The hopper was filled with the seeds. The seed drill was hitched to the tractor. It was raised up with the help of the hydraulic system and the tractor was moved forward over a distance. The seed drill was then lowered down and moved forward for a short distance. The delivery of seeds was observed for both raised and lowered conditions.

The height, width, length, row spacing, working width and hopper capacity were measured to obtain the general specifications.

*Observation* : The seed drill along with the MF-1035 tractor has been shown in Fig. 11.7. It is observed that seeds are not delivered on the ground surface in raised position of the seed drill. But delivery of seeds in all the 9 rows is found in lowered position of the seed drill with forward motion. The general specifications are found to be

| | |
|---|---|
| Height including tiller, mm | 1117 |
| Width including tiller, mm | 2184 |
| Length including linkage, mm | 1600 |
| Maximum sowing width, mm | 2133 |
| Minimum row spacing, mm | 177 |
| Hopper capacity, litre | 85 |



1. Drive wheel
2. Furrow opener
3. Main frame
4. Hitch
5. Seed box
6. Seed control lever

ALL DIMENSIONS IN MM

Fig. 11.7. Tractor-operated seed drill

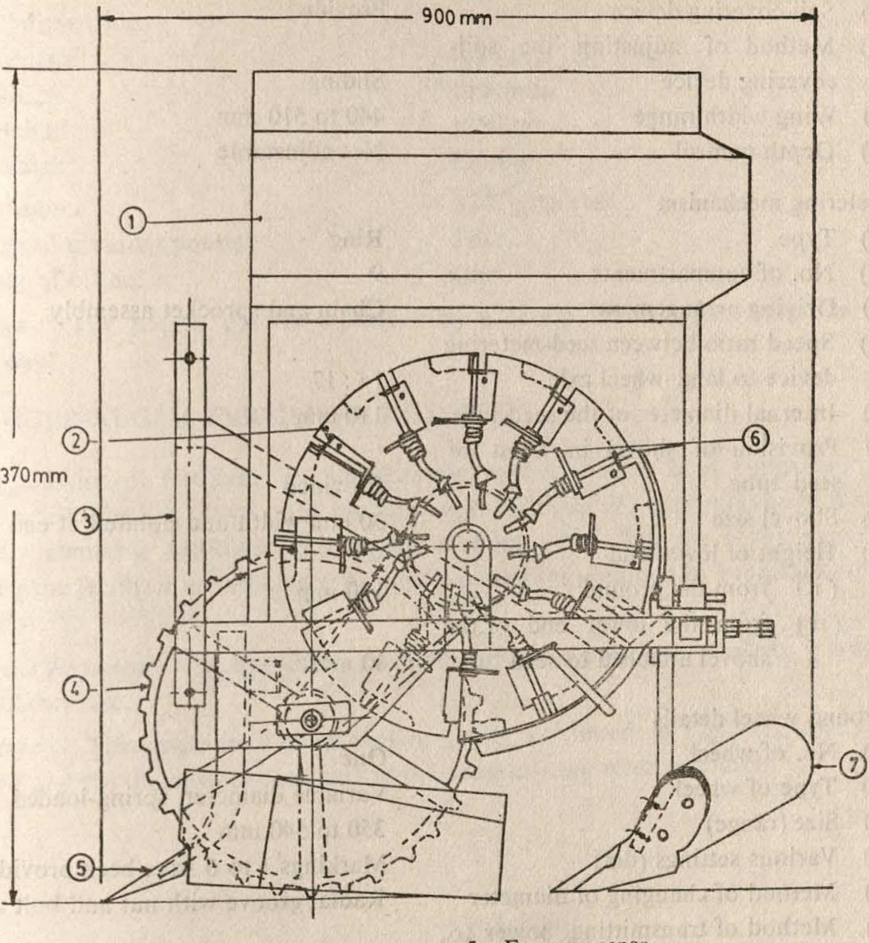
*Remarks* : Provision has been made to divide the hopper into 9 compartments by putting partition plates. This may be done to sow different seeds in separate rows.

## 11.5 POTATO PLANTER

Small potato seeds are sown in singles. When the seed potatoes are larger in size, seed pieces cut from the whole tubers are planted. The potato seeds are planted by automatic or semi-automatic potato planters.

*Materials Required* : Semi-automatic potato planter, scales, tape and toolbox, etc.

*Procedure* : The planter was examined. As far as practicable some measurements were taken directly ; some of the features were noted through inspection and the remaining details from the manufacturer's manual. Based on this a line sketch was drawn (Fig. 11.8) and some relevant parts were labelled.



1. Hopper
2. Picker wheel
3. Main frame
4. Ground wheel
5. Furrow opener
6. Picker arm
7. Ridger

Fig. 11.8. Potato planter

*Observation* : The following specifications of the planter were noted :

| | |
|---|---|
| 1. General | |
| (a) Name | Shera Field |
| (b) Type | Semi-automatic two-row |
| (c) Make | Shera Motor and Tractor Engineering Works<br>Nehru Garden Road, Jullunder City, Punjab |
| 2. Ridgers | |
| (a) Number of ridgers | Three |
| (b) Method of changing of ridge | Hole provided on the frame of ridge |
| (c) Range of spacing | 620 to 800 mm |

| | |
|---|---|
| (d) Soil-covering device | Provided |
| (e) Method of adjusting the soil-covering device | Sliding |
| (f) Wing width range | 440 to 510 mm |
| (g) Depth control | Not adjustable |
| 3. Metering mechanism | |
| (a) Type | Ring |
| (b) No. of compartments | 9 |
| (c) Driving arrangement | Chain and sprocket assembly |
| (d) Speed ratio between seed-metering device to land wheel axle | 14 : 17 |
| (e) Internal diameter of the seed tube | 110 mm |
| (f) Provision of shovel in front of seed tube | Provided |
| (g) Shovel size | 30 mm width and pointed at end |
| (h) Height of lower end | |
| ( i ) from the ground | 180 mm |
| ( ii ) from the lower end of the shovel attached to seed tube | 40 mm |
| 4. Ground wheel details | |
| (a) No. of wheel | One |
| (b) Type of wheel | Variable diameter, spring-loaded |
| (c) Size (range) | 350 to 540 mm |
| (d) Various settings (dia) | Markings 1 to 6 have been provided |
| (e) Method of changing of diameter | Radial groove with nut and bolt assembly |
| (f) Method of transmitting power to feed belt | Chain and sprocket |
| 5. Frame | |
| (a) Type | Square |
| (b) Provision for change of row spacing | Holes at 25 mm interval |
| 6. Operator's seat | |
| (a) Type | Rigid |
| (b) Diameter | 100 mm |
| (c) Distance of centre of seat from hopper edge | 500 mm |
| (d) Foot supports | Not provided |
| 7. Hopper | |
| (a) Capacity | 1·5 quintals |
| (b) Type | Trapezoidal |

| | |
|---|---|
| 8. Type of hitch | Suitable for three-point linkage hitch system |
| 9. Overall dimensions | |
| (a) Length | 1850 mm |
| (b) Width | 1500 mm |
| (c) Height | 1250 mm |
| (d) Weight | 250 kg |
| 10. Power source | 35-h.p. tractor |
| 11. Number of greasing points | Four |
| 12. Number of oil holes | One |

*Remarks* : The potato planter operated by a 35-h.p. tractor can cover an area of 1 to 1·5 ha/day.

## 11.6 PLUNGER-AUGER FERTILIZER INJECTOR

The application of fertilizer by broadcasting method in low land transplanted paddy results in excessive fertilizer loss. The plunger-auger fertilizer injector puts the urea and other commercially available fertilizers at a depth of about 4 cm. The use of this machine helps in increasing the fertilizer use efficiency from 30 per cent (as obtained by broadcasting method) to 65 per cent.

*Materials Required* : Plunger-auger fertilizer injector, scale, tape, toolbox, platform-type weighing balance, etc.

*Procedure* : This machine was studied in detail as viewed in Figs. 11.9 and 11.10. It was weighed and the dimensions (outlined in the observations) were measured.

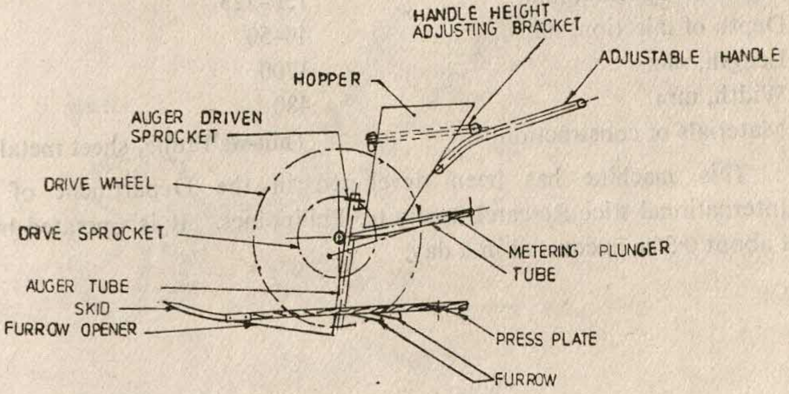


Fig. 11.9. Schematic diagram of plunger-auger fertilizer injector

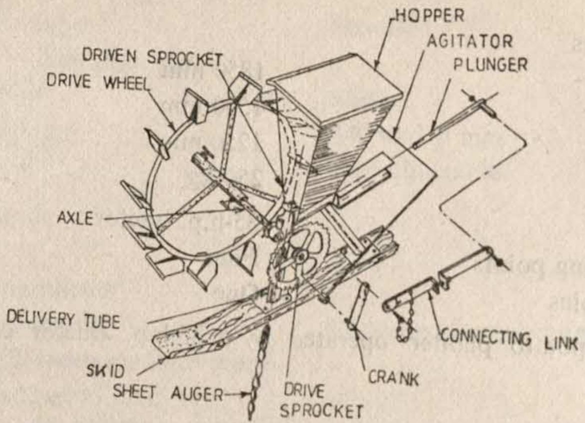


Fig. 11.10. View of plunger-auger fertilizer injector showing the left side plunger-auger assembly

*Observation* : It is a two-row machine to inject prilled or fine granules of fertilizer at a depth of 4 cm. It has two hoppers. Each hopper is fitted with a reciprocating plunger to deliver the desired amount of fertilizer. The hopper is fitted with agitator to ensure smooth flow of the fertilizer. The desired amount of fertilizer is delivered into the fertilizer-injecting tube having rotating sheet auger. The auger conveys and forces the fertilizer into the furrow opened by the furrow opener. The furrow closer pushes the soil back into the furrow and covers the injected fertilizer in the soil.

*Specifications*

| | |
|---|---|
| Hopper capacity, kg | 2 |
| Weight without fertilizer, kg | 8 |
| Width covered per pass | 4 plant rows |
| Plant row spacing, mm | 150–225 |
| Depth of injection, mm | 40–50 |
| Length, mm | 1700 |
| Width, mm | 480 |
| Materials of construction | Thin-wall tube, sheet metal |

*Remarks* : This machine has been developed in the Department of Agricultural Engineering, International Rice Research Institute, Philippines. It is operated by one person and an area of about 0·5 ha is covered in a day.

# 12

# Interculture Implements

## 12.1 WHEEL HOE

Controlling the growth of weeds on agricultural field is considered to be one of the most important operations. The effective and timely control of the weeds results in higher production. The mechanical control of weeds by using improved weeders is more effective and economic.

*Materials Required* : Wheel hoe, tape, scale, callipers, toolbox, platform-type weighing balance, etc.

*Procedure* : Based on the available wheel hoe a line sketch was drawn (Fig. 12.1) and its various parts were labelled. It was weighed and dimensions were measured. The remaining details were noted from the manufacturer's leaflet.

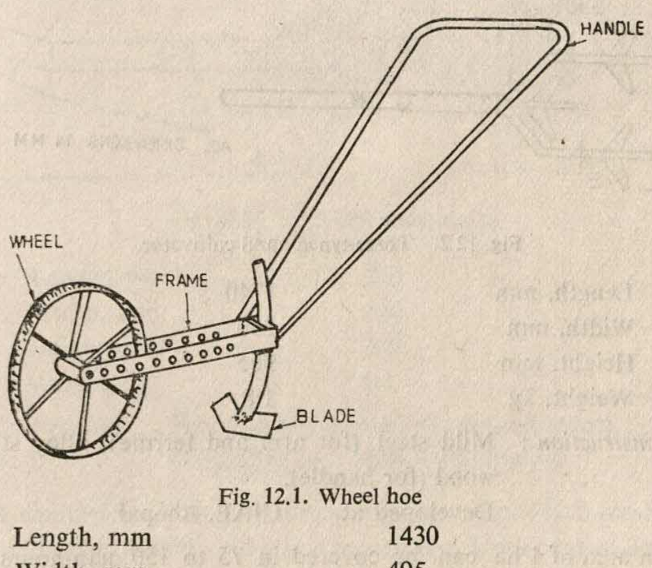


Fig. 12.1. Wheel hoe

*Observation* :

| | |
|---|---|
| Length, mm | 1430 |
| Width, mm | 495 |
| Height, mm | 1000 |
| Weight, kg | 9·5 |

*Materials of construction* : Mild steel, medium carbon steel and conduit pipe.

Developed at CIAE, Bhopal.

*Remarks* : This wheel hoe is used in between crop rows for interculture and weeding operations. Adjustable sweeps and shovels can be fitted to this to suit in different soil and crop conditions. It is suitable for upland crops. It is operated by one person. An area of 1 ha can be covered in 60–100 man-hours.

## 12.2 THREE-TYNED HAND CULTIVATOR

The three-tyned hand cultivator is a pull-type weeder suitable for upland row crops. Higher output is achieved with this weeder under favourable conditions.

*Materials Required* : Three-tyned hand cultivator, scale, tape, callipers, toolbox and platform-type weighing balance, etc.

*Procedure* : The components of the cultivator were identified and their dimensions were measured. Its weight was taken and the sketch was drawn (Fig. 12.2).

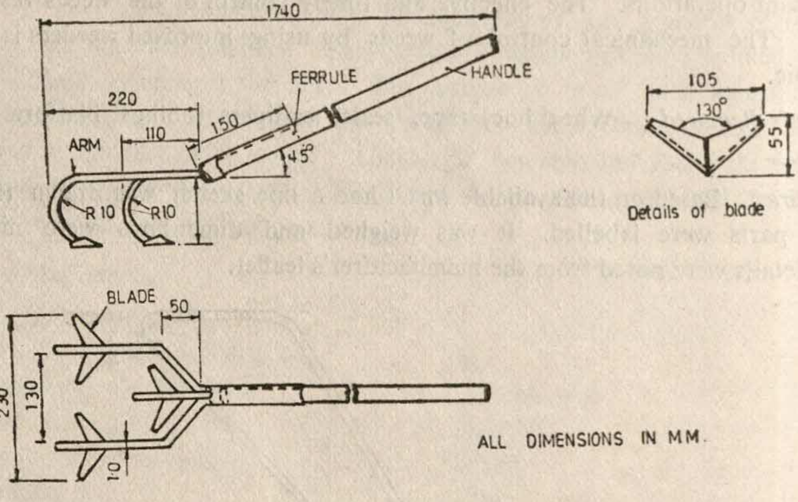


Fig. 12.2. Three-tyned hand cultivator

| | | |
|---|---|---|
| *Observations* : | Length, mm | 1740 |
| | Width, mm | 230 |
| | Height, mm | 965 |
| | Weight, kg | 1·8 |

*Materials of Construction* : Mild steel (for arm and ferrule), alloy steel (for blade) and wood (for handle).

Developed at CIAE, Bhopal.

*Remarks* : An area of 1 ha can be covered in 75 to 150 man-hours for weeding. The sweep-type blades provided with this weeder work effectively during early stages of crop growth. The weeds mixed with the soil create a soil mulch which helps in moisture conservation.

## 12.3 PUSH-TYPE HAND WEEDER

The push-type hand weeder is simple in construction and is suitable for weeding in low land rice transplanted in rows. It is available in different sizes to meet the various row spacings.

*Materials Required* : Push-type hand weeder, tape, scale, callipers, toolbox and platform type-weighing balance, etc.

*Procedure* : The weeder was weighed and its length, width and height were measured. The various parts were drawn and labelled (Fig. 12.3).

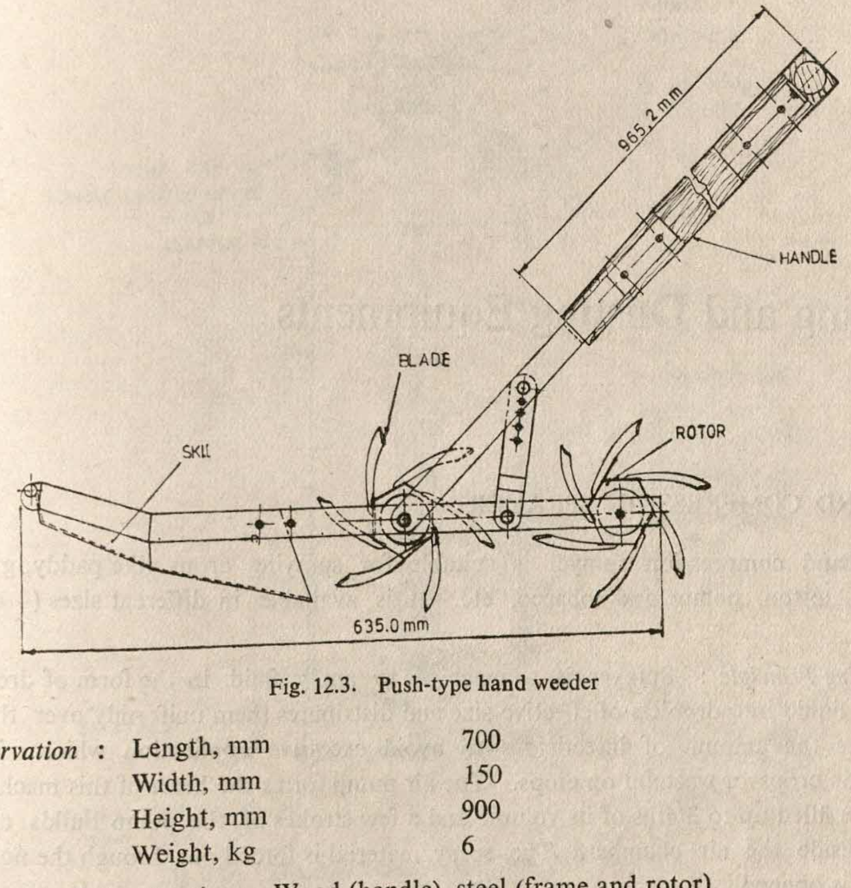


Fig. 12.3. **Push-type hand weeder**

| | | |
|---|---|---|
| *Observation* : | Length, mm | 700 |
| | Width, mm | 150 |
| | Height, mm | 900 |
| | Weight, kg | 6 |

*Materials of Construction* : Wood (handle), steel (frame and rotor).

Developed at : IRRI, Philippines.

The weeder is equiped with two spiked wheels or rotors which rotates on a supporting frame. The front end forms a skid. The skid serves as a depth control device for the rotors.

*Remarks* : It is operated by one person and covers an area of 1 ha in 35 to 75 man-hours.

# 13

# Spraying and Dusting Equipments

## 13.1 HAND COMPRESSION SPRAYER

The hand compression sprayer is suitable for spraying crops like paddy, groundnut, vegetables, cotton, potato and tobacco, etc. It is available in different sizes (4 to 13 litre capacity).

*Working Principle* : Sprayer is a machine to apply fluid in the form of droplets. It breaks the liquid into droplets of effective size and distributes them uniformly over the plants. It regulates the amount of insecticides to avoid excessive application which might prove harmful for crops or wasteful on crops. The air pump forms the heart of this machine. The container is filled up to 3/4ths of its volume and a few strokes of the pump builds up enough pressure inside the air chamber. The spray material is forced out through the nozzle when the nozzle is opened.

*Materials Required* : Marut hand compression sprayer, scale, tape, balance, measuring cans and cylinder, water, toolbox, weighing balance, etc.

*Procedure* : The hand compression sprayer was weighed. Its capacity was measured by pouring measured quantity of water with the help of measuring cylinder. The height and diameter were measured. It was then dismantled and the different parts and accessories were identified and observed and figures were drawn accordingly (Figs. 13.1 to 13.3).

*Observation* : The sprayer studied here consists of the following parts (vide Figs. 13.2 and 13.3) as detailed in Table 13.1.

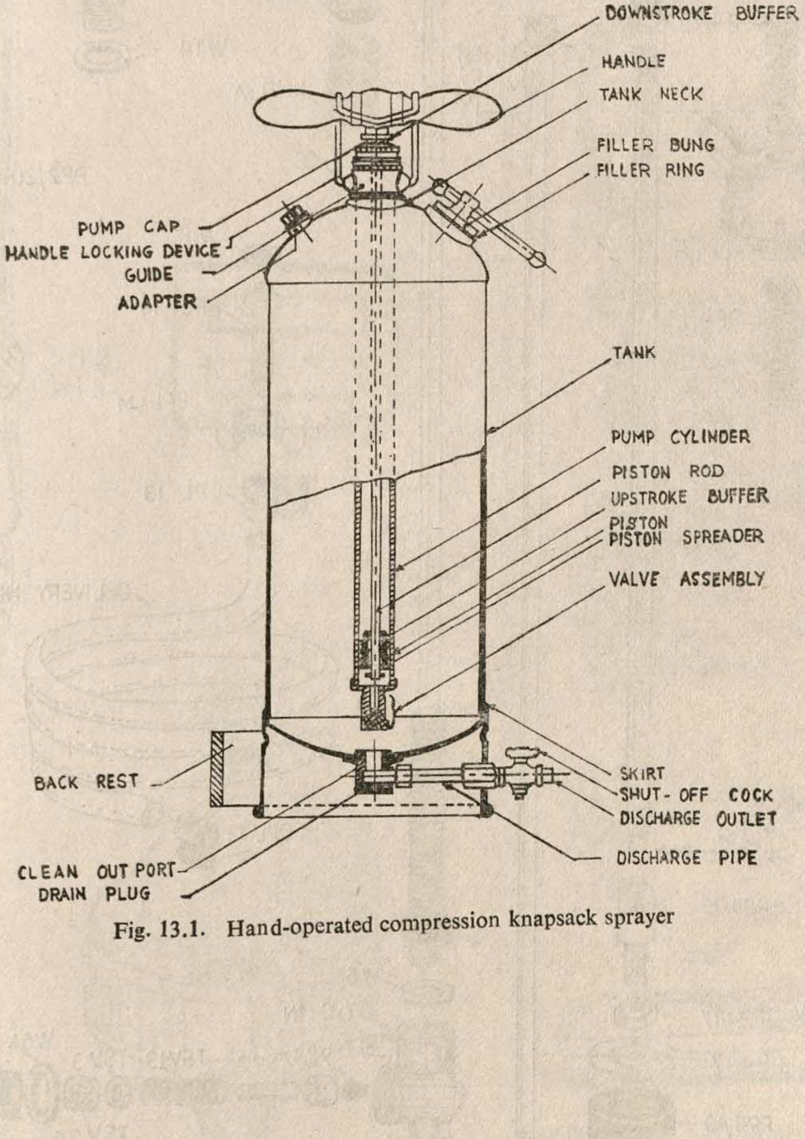


Fig. 13.1. Hand-operated compression knapsack sprayer

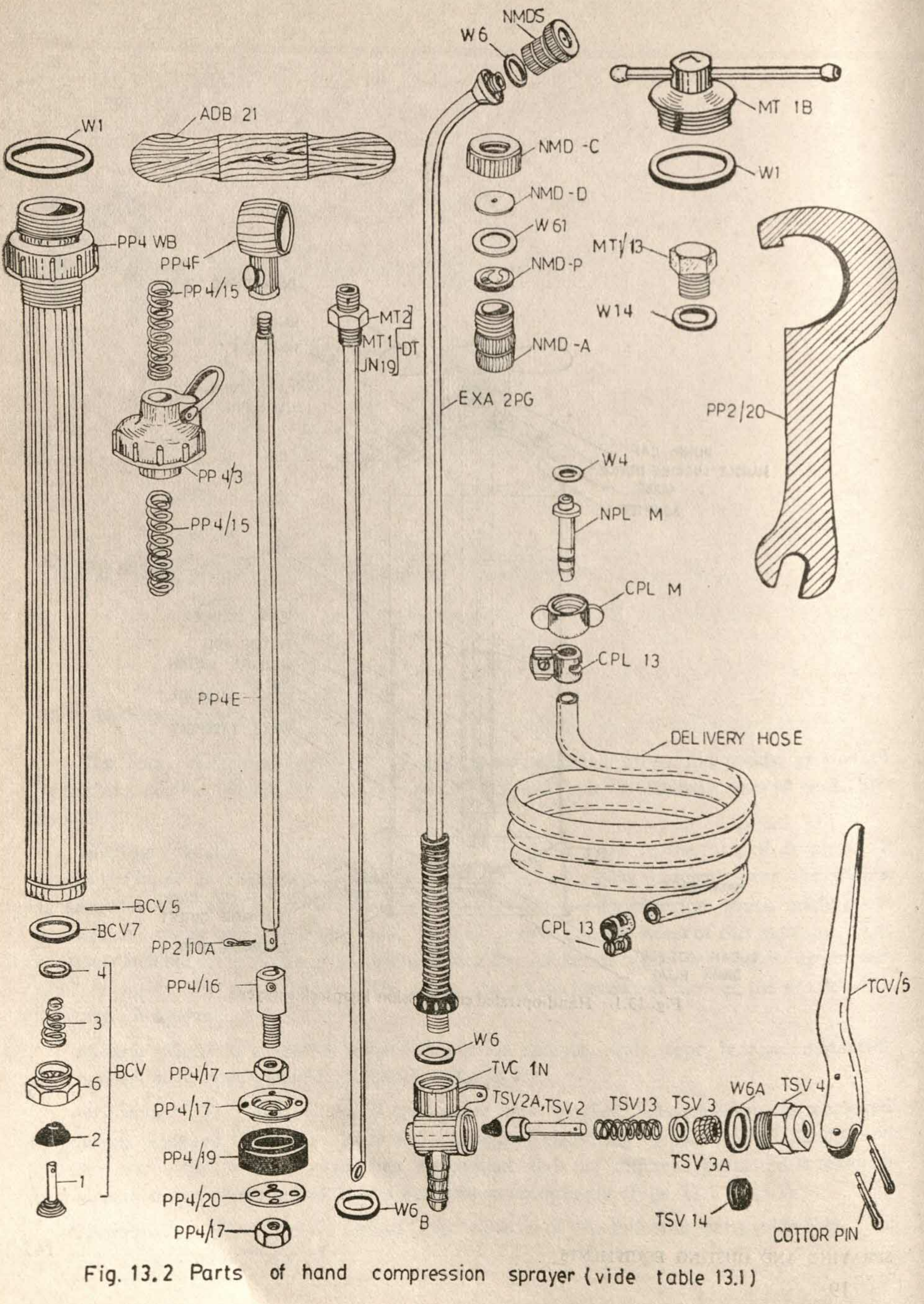


Fig. 13.2 Parts of hand compression sprayer (vide table 13.1)

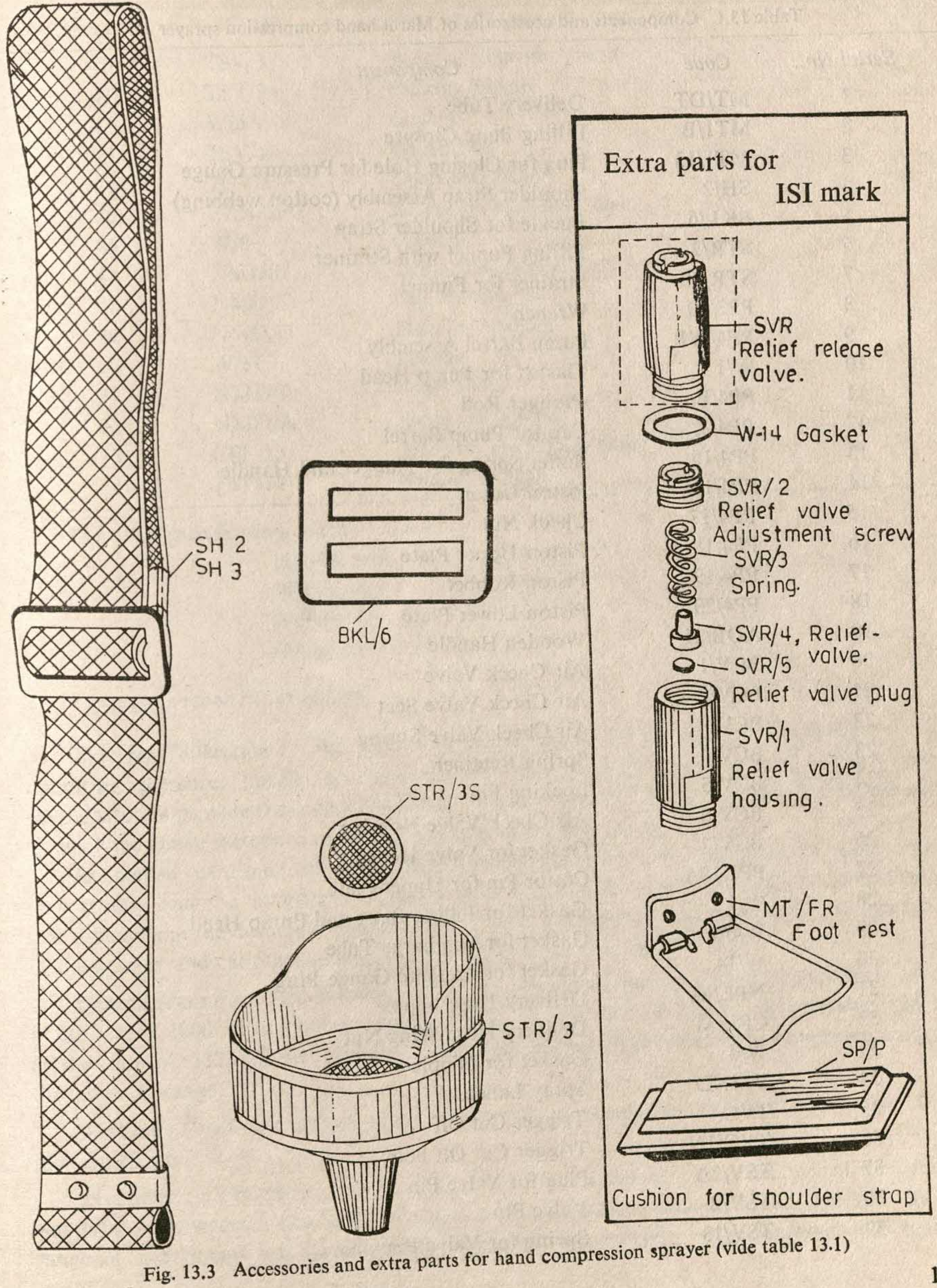


Fig. 13.3 Accessories and extra parts for hand compression sprayer (vide table 13.1)

Table 13.1 Components and accessories of Marut hand compression sprayer

| *Serial No.* | *Code* | *Component* |
|---|---|---|
| 1 | MT/DT | Delivery Tube |
| 2 | MT1/B | Filling Bung Closure |
| 3 | MT1/13 | Plug for Closing Hole for Pressure Gauge |
| 4 | SH/2 | Shoulder Strap Assembly (cotton webbing) |
| 5 | BKL/6 | Buckle for Shoulder Strap |
| 6 | STR/3 | Filling Funnel with Strainer |
| 7 | STR/3S | Strainer for Funnel |
| 8 | PP2/20 | Wrench |
| 9 | PP4/WB | Pump Barrel Assembly |
| 10 | W/1 | Gasket for Pump Head |
| 11 | PP4/E | Plunger Rod |
| 12 | PP4/3 | Cap for Pump Barrel |
| 13 | PP4/15 | Buffer Spring for Plunger and Handle |
| 14 | PP4/16 | Piston Union |
| 15 | PP4/17 | Check Nut |
| 16 | PP4/18 | Piston Upper Plate |
| 17 | PP4/19 | Piston Rubber |
| 18 | PP4/20 | Piston Lower Plate |
| 19 | ADB/21 | Wooden Handle |
| 20 | BCV/1 | Air Check Valve |
| 21 | BCV/2 | Air Check Valve Seat |
| 22 | BCV/3 | Air Check Valve Spring |
| 23 | BCV/4 | Spring Retainer |
| 24 | BCV/5 | Locking Pin |
| 25 | BCV/6 | Air Check Valve Housing |
| 26 | BCV/7 | Gasket for Valve Housing |
| 27 | PP2/10A | Cottor Pin for Upper Plate |
| 28 | W/1 | Gasket for Filling Bung and Pump Head |
| 29 | W/6B | Gasket for Discharge Tube |
| 30 | W/14 | Gasket for Pressure Gauge Plug |
| 31 | NPL/M | Delivery Hose Nipple |
| 32 | CPL/M | Delivery Hose Wing Nut |
| 33 | W/4 | Gasket for Nipple |
| 34 | VMND | Spray Lance |
| 35 | TVC | Trigger Cut Off |
| 36 | TVC/1N | Trigger Cut Off body |
| 37 | TSV/2A | Plug for Valve Pin |
| 38 | TSV/2 | Valve Pin |
| 39 | TSV/13 | Spring for Valve Pin |

| Serial No. | Code | Component |
|---|---|---|
| 40 | TSV/3 | Packing Retainer Collar |
| 41 | TSV/3A | Packing Twine |
| 42 | W/6A | Gasket |
| 43 | TSV/4 | Gland Nut |
| 44 | TCV/5 | Operating Lever |
| 45 | EXA/2PG | Extension Rod with Grip |
| 46 | W/6 | Gasket |
| 47 | NMDS | Duro Mist Spray Nozzle |
| 48 | NMD/C | Cap for Nozzle |
| 49 | NMD/D | Disc for Nozzle |
| 50 | W/61 | Gasket |
| 51 | NMD/P | Swirl Plate |
| 52 | NMD/A | Body for Nozzle |
| 53 | CPL/13 | Delivery Hose Clip Screw Type |
| 54 | TSV/14 | Gland Washer |

*The other specifications are* :

| | |
|---|---|
| Height, mm | 650 |
| Width, mm | 590 |
| Weight, kg | 4·5 |
| Capacity, litres | 9 |

### 13.1.1 CALIBRATION OF SPRAYER

*Need for Calibration* : The rate of application of a spray fluid is regulated by the operating pressure, nozzle aperture, swath width and speed of the operator. Some manufacturers provide the calibration chart that may be used to set out the various combinations of the above factors to obtain a particular application rate.

In course of time, the pump and nozzle get worn out, the pressure gauge reads inaccurately and the strainer and nozzle gets chocked as a result of which the discharge rate differs from the designed discharge rate. It is, therefore, essential to check the operation of the sprayer and calibrate it before application of the spray fluid.

*Control Measure* : Quinalphos 25 EC or monocrotophos 40 EC or fenitrothion 50 EC at the rate of 1000 ml or phosphamidon 100 EC at the rate of 375 ml or phosalone 35 EC at the rate of 1125 ml per hectare in 500 litres (50 cc/m$^2$) of water is to be sprayed ensuring thorough coverage.

*Materials Required* : Hand compression sprayer, measuring cylinder, can, water, tape, stop watch, etc.

*Procedure* : Ten plots each of $2{\cdot}5 \times 4{\cdot}0$ m were selected. The container of the sprayer was filled with water. The level of water in the container was marked. Pressure in the range of 3–5 kg/cm$^2$ was developed and one plot was sprayed. The container was refilled with water to the previous level by adding a known quantity with the help of a measuring cylinder. The process was repeated for the remaining nine plots.

*Observation* : The volume of water sprayed in each plot are presented below :

Table 13.2 Observed spray volume in different plots

| *Serial No.* | *Plot* (10 m$^2$) | *Actual volume of spray* (cm$^3$) | *Actual application rate* (lit/ha) |
|---|---|---|---|
| 1 | *A* | 510 | 510 |
| 2 | *B* | 485 | 485 |
| 3 | *C* | 520 | 520 |
| 4 | *D* | 495 | 495 |
| 5 | *E* | 515 | 515 |
| 6 | *F* | 490 | 490 |
| 7 | *G* | 495 | 495 |
| 8 | *H* | 515 | 515 |
| 9 | *I* | 525 | 525 |
| 10 | *J* | 520 | 520 |
| Average | | 507 | 507 |

*Conclusion* : On an average the application is slightly more than the required. Hence, it is alright.

*Remarks* : In case of appreciably lower or higher rate the operator speed and/or the nozzle pressure has to be adjusted suitably to set the desired rate of application. The hand compression sprayers are suitable for small areas only.

## 13.2 MIST BLOWER-CUM-DUSTER

This is a power operated sprayer-cum-duster. It is used to cover large areas with small quantity of chemical. The frequent filling up and continuous pumping as required in hand compression sprayer is avoided by the use of this machine.

*Operation* : It is operated by a small internal combustion engine. The pressure pump ensures a constant steady pressure and operates at pressure ranging between 20 and 55 kg/cm$^2$. The liquid delivery pipe is replaced by a dust outlet pipe when the machine is used as a duster.

*Materials Required* : Aspee Bolo mist blower-cum-duster, scale, tape, water, powder, tool-box, platform type weighing machine, etc.

*Procedure* : The mist blower-cum-duster was studied, its different components were identified and arrangements were observed. The common device for both spraying and dusting units was disengaged and studied separately from two uncommon attachments. Then the dust outlet pipe and pleated hose were fitted to it. The tank was filled with dust/powder. The engine was started and dusting operation was conducted. The engine was stopped ; the dusting unit was detached and dust was removed from the tank. The spraying unit was fitted and tank was filled with water. The machine was operated to observe the spraying operation. The machine was weighed and its common dimensions were measured.

*Observation* : The details of the spraying and dusting units are presented in Figs. 13.4 and 13.5, respectively. The specifications are :

| | |
|---|---|
| Length, mm | 400 |
| Width, mm | 350 |
| Height, mm | 460 |
| Weight, kg | 11·5 |
| Manufacturer | M/s American Spring and Pressing Works Pvt. Ltd., Bombay |

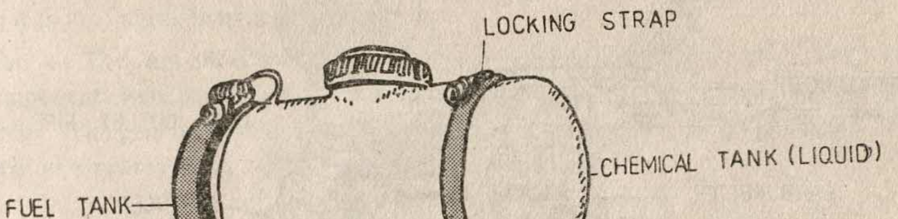


Fig. 13.4. Power-operated sprayer

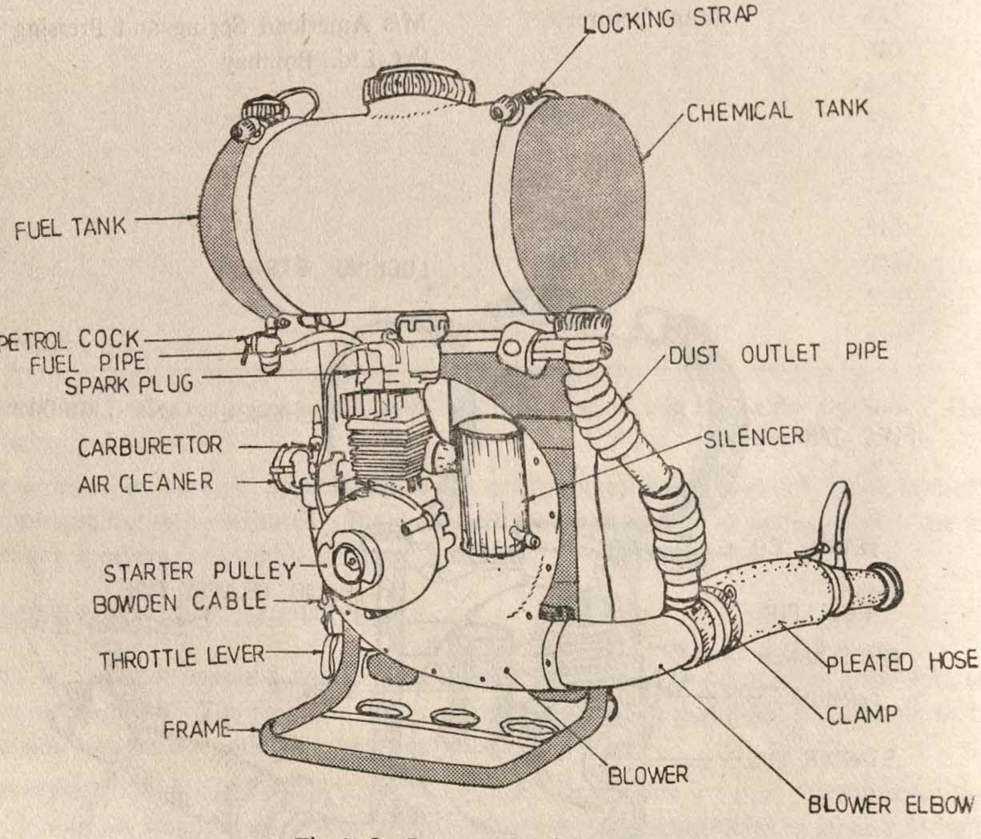


Fig. 13.5. Power-operated duster

# 14

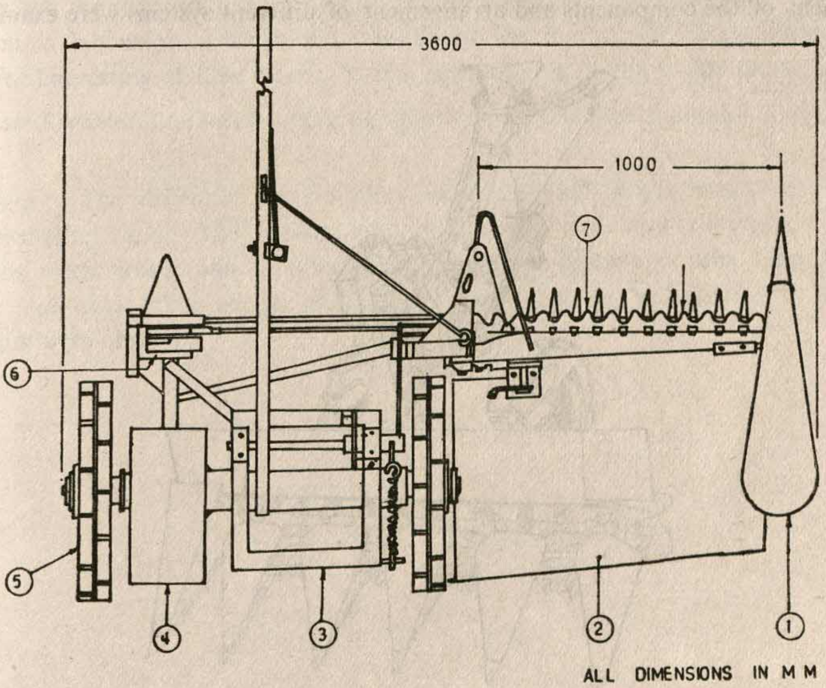
# Harvesting Equipments

## 14.1 ANIMAL-DRAWN ENGINE-OPERATED REAPER

The harvesting of crops by the sickle is one of the most time consuming and labourious operations of farming. Animal-drawn harvesters have been developed and tested at Allahabad Agricultural Institute, Allahabad ; Indian Agricultural Research Institute, New Delhi and Punjab Agricultural University, Ludhiana.

*Materials/Items Required* : Animal-drawn engine-operated reaper, scale, tape, and tool-box, petrol, a pair of animals with ploughman, etc.

*Procedure* : The animal-drawn engine-operated reaper was studied (Fig. 14.1) and its different components were examined. The arrangements of different components and systems were observed. The general specifications were measured and noted. The reaper was hitched and operated on a nearby field. The work of the reaper was observed.



1. Swath divider, 2. Platform, 3. Frame, 4. 2 h.p. petrol engine,
5. Land wheel, 6. Pitman wheel, 7. Cutter bar

Fig. 14.1. Animal-drawn engine-operated reaper

*Observation* : The unit consists of a cutter bar and a platform. The cutter bar is powered by a 2-h.p. petrol engine. It cuts the crop, places it on the platform with the help of a rake. The rake is operated manually. The bunches formed on the reaper are dropped and cleared manually for the next run. The following specifications are observed :

| | |
|---|---|
| Length, mm | 3600 |
| Width, mm | 2875 |
| Height, mm | 1225 |
| Width of coverage, mm | 1000 |
| Type | Animal-drawn engine-operated cutter bar |
| Developed at | CAE, Punjab Agricultural University, Ludhiana, Punjab |

## 14.2 POWER TILLER MOUNTED REAPER WINDROWER

Harvesting done immediately after maturity reduces the field loss. Quick harvesting allows more time for field preparation for the next crop. With such a view power tiller operated harvester has been developed for harvesting of cereal crops.

*Materials Required* : Power tiller operated reaper windrower, scale, tape, diesel, toolbox, etc.

*Procedure* : The components of the power tiller mounted reaper were studied (Fig 14.2). The placement of the components and arrangement of different systems were examined. The

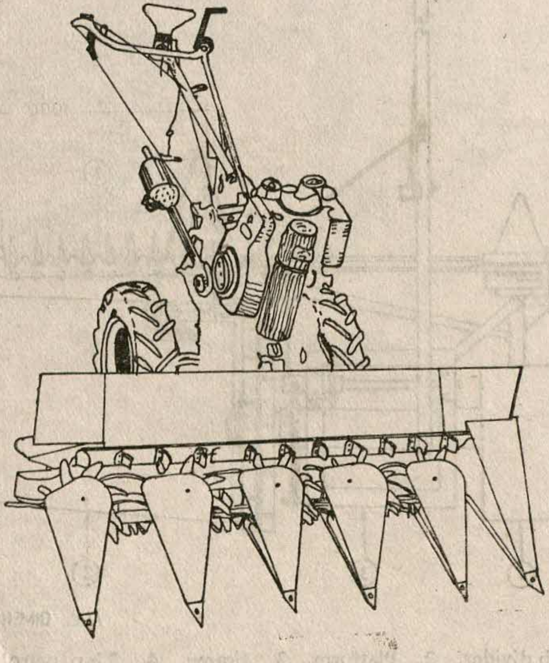


Fig. 14.2. Power tiller front mounted reaper windrower

general specifications were observed/measured and noted. It was taken to a field and its work was observed.

*Observation* : The reaper is mounted on the front of the power tiller and has a vertical conveyor unit. The machine cuts the crop and conveys the materials to one side in the form of a windrow. The cut crop is manually collected and tied for transportation. The machine consists of a gearbox, cutter bar, conveyor belt and star wheel, etc. The following general specifications are observed :

| | |
|---|---|
| Length, mm | 2850 |
| Width, mm | 1900 |
| Height, mm | 1270 |
| Width of cut, mm | 1600 |
| Type | Power tiller front mounted |
| Cutter bar | Reciprocating type |
| Developed at | CIAE, Bhopal |

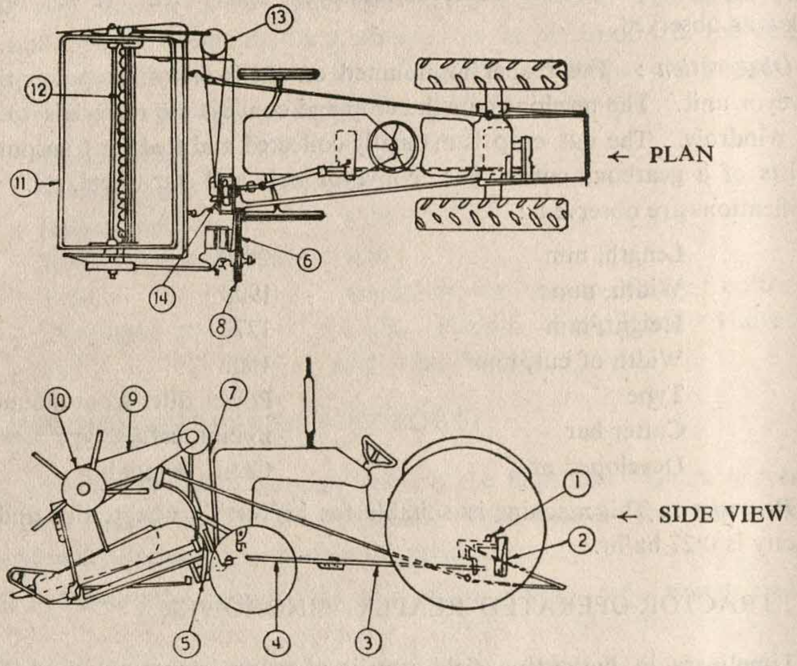
*Remarks* : This machine is suitable for harvesting wheat, rice and oats, etc. The field capacity is 0·27 ha/hr.

## 14.3 TRACTOR-OPERATED REAPER WINDROWER

Timeliness in harvesting field crop is of prime importance since much has been invested in the crop and the risks are high. At present harvesting is done by sickle. It takes a lot of time and is labourious. Therefore, attachment like tractor-operated reaper has been developed for harvesting of field crops. It also increases the utility of the tractor in the farm.

*Materials Required* : Tractor-operated reaper windrower, 35-h.p. tractor, scale, tape, toolbox, etc.

*Procedure* : The different parts of the tractor-mounted reaper windrower were studied and identified (Fig. 14.3). The arrangement of different units was observed. The general specifications were noted and in some cases measured. The reaper was then attached to the tractor and was taken to the field. It was operated in the field and the works of the different units were observed.



1. Tractor PTO
2. Belt drive
3. Propeller shaft
4. Telescopic drive shaft
5. Gearbox
6. Drive belt for apron driving pulley
7. Drive belt for reel driving pulley
8. Apron driving pulley
9. Drive belt for reel
10. Reel driving pulley
11. Reel
12. Cutter bar
13. Pitman wheel
14. Spur gear

Fig- 14.3. Tractor-operated reaper windrower

*Observation* : The reaper windrower consists of cutter bar, apron conveyor and reel. These units get power from the PTO shaft of the tractor. The machine is mounted on the front of the tractor. The crop is cut, carried on to the conveyor and delivered in the form of windrow. The following specifications are observed :

| | |
|---|---|
| Length, mm | 2200 |
| Width, mm | 840 |
| Height, mm | 610 |
| Width of cut, mm | 2050 |
| Type | Tractor front mounted |
| Cutter bar | Reciprocating type |
| Developed at | CIAE, Bhopal |

*Remarks* : It is suitable for harvesting wheat, rice and oats, etc. The field capacity of the reaper is 0·26 ha/hr.

## 14.4 POTATO DIGGER-CUM-ELEVATOR

It is a tractor rear mounted machine for harvesting of potato crop.

*Materials Required* : Potato digger-cum-elevator, 35-h.p. tractor, scale, tape and toolbox, etc.

*Procedure* : The different parts of the machine were identified and studied (Figs. 14.4 and 14.5). The detail features of the machine were seen from the manufacturer's manual. Some of the measurements were taken to test the specifications. The machine was hitched to the tractor and taken to the field. It was operated and the works of the different units were observed.

*Observation* : The potato digger-cum-elevator has two triangular blades partitioned by two discs which move together in between the two ridges. Two more discs, one each at the extreme ends of digging blades are mounted to prevent the side spilling of the dug potato and soil mass. The elevator is powered by the PTO shaft. The potatoes thus exposed from the soil are collected by hand picking.

Following specificatians are observed for the potato digger-cum-elevator :

Overall dimensions :

| | |
|---|---|
| Length, mm | 2540 (with telescopic shaft) |
| Width, mm | 1500 |
| Height, mm | 1180 (without wheels) |
| Hitch | Category I |

Blade :

| | |
|---|---|
| No. of blades | 2 |
| Width, mm | 440 |
| Clearance from ground, mm | 100 |
| Distance between blades, mm | 619 (centre to centre) |
| Thickness, mm | 6·6 to 7·2 |

Main frame :

| | |
|---|---|
| Channel (mm × mm × mm) | 70×40×6·5 |
| Angle (mm × mm × mm) | 40×40×5·5 |
| Flat (mm × mm) | 50×12·5 |

Elevator chain conveyor :

| | |
|---|---|
| Length, mm | 2850 |
| Width, mm | 1250 |
| Pitch, mm | 25·6 to 34·8 |
| Chain rod dia, mm | 12·5 |
| No. of rods | 76 |
| Flat belt, mm | 48 (4 ply) |
| Slope of elevator | 165° to 23° |

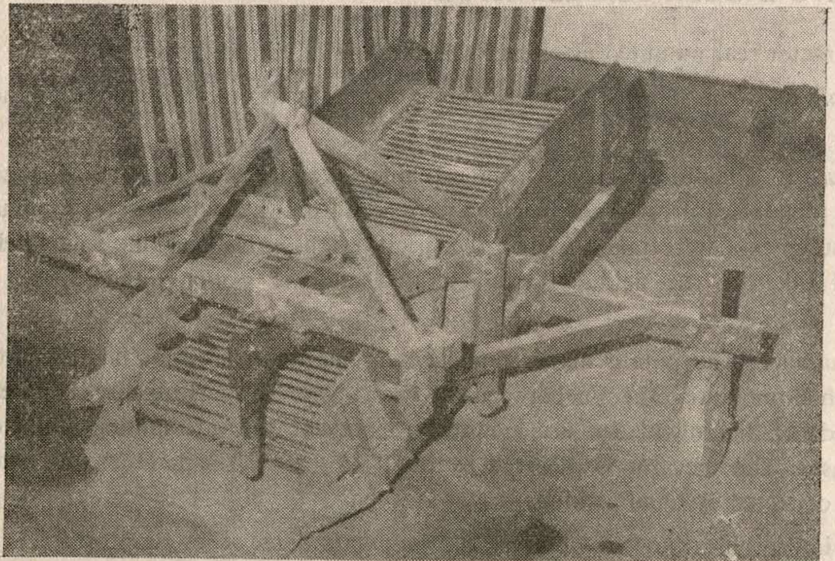


Fig 14.4. Potato digger-cum-elevator

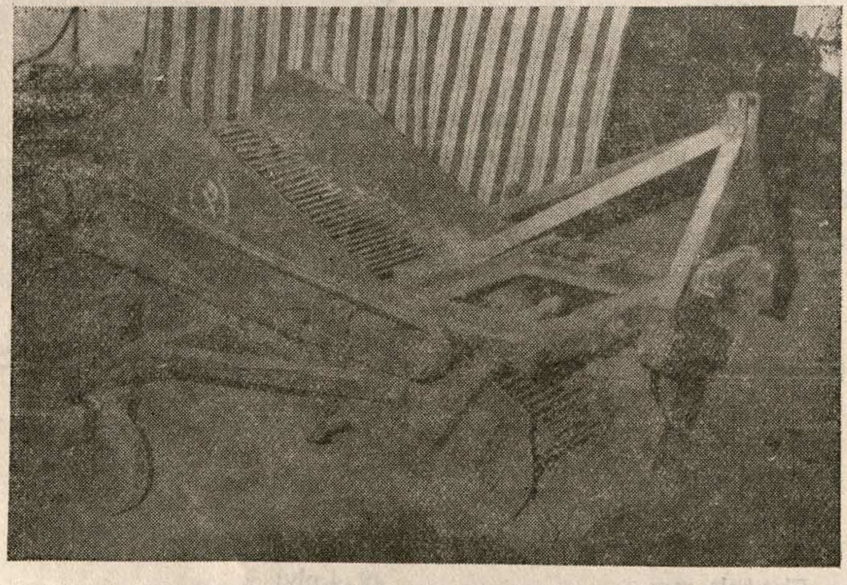


Fig 14.5. Belt and pulley arrangement for elevator operation

Disc :

| | |
|---|---|
| Diameter, mm | 500 |
| No. of discs | 4 |
| Hub dia, mm | 88·5 |
| Spacing between the central discs, mm | 160 |
| Spacing between the two extreme discs, mm | 1065 |

Transmission :

| | |
|---|---|
| Rear pulley dia, mm | 175 |
| Front pulley dia, mm | 245 |
| V-belt size, mm | 343 (2 nos.) |
| Gearbox reduction ratio | 13 : 3 |
| V-belt tightener, mm | 80 (width), 60 (dia) |
| Output shaft dia, mm | 57·5 |
| Rear drive shaft dia, mm | 38 |
| Idler shaft dia (at bearing), mm | 28·5 |
| Agitator shaft dia, mm | 28·5 |
| Idler roller shaft dia, mm | 28·5 |
| Front idler shaft dia, mm | 32 |
| Driving sprocket teeth, nos. | 18 |
| Agitator teeth, nos. | 8 |
| Weight, kg | 465 |
| Manufacturer | M/s Shera Motor and Tractor Engineering Works,<br>Nehru Garden Road,<br>Jullundhar-1 |

*Remark* : Its working capacity is about 50 man-cum-machine hour per hectare.

# 15

# Threshers

## 15.1 ROTARY PADDY THRESHER

In various parts of the country the removal of grain from the panicle is accomplished by treading the grain under the feet of men or the hooves of the animals. With the non-availability of labour in peak period and for the comfort of the worker, the pedal threshers are used in many farms.

*Materials Required* : Rotary paddy thresher, scale, tape, toolbox, tachometer, etc.

*Procedure* : The rotary paddy thresher was placed on a level surface. The various components were studied and identified (Fig. 15.1 and Table 15.1). The arrangement of different parts was seen. The arrangement for transmission of power from wooden board to drum shaft was studied. The gear covers were removed and number of teeth for each gear was counted to determine the speed ratio. The gear covers were replaced. It was operated and its working was observed. The speed of the drum was recorded by the tachometer. Some of the dimensions were measured.

*Observation* : The thresher consists of a threshing cylinder, driving mechanism and supporting frame. To achieve the optimum cylinder speed of 400 r.p.m. (approx), an overall speed ratio of 1 : 4 has been provided in the driving mechanism through two cast-iron gears. The wooden cylinder is provided with peg type teeth. The cylinder is supported by two ball bearings. The threshing of paddy is achieved by holding the bundles against the rotating cylinder.

The measured dimensions are :

| | |
|---|---|
| Length, mm | 740 |
| Width, mm | 640 |
| Height, mm | 660 |
| Diameter of drum, mm | 450 |
| Length of drum, mm | 500 |
| Length of slat or spoke, mm | 480 |
| Slats or spokes, nos. | 12 |
| Spikes in each slat, nos. | 10 |
| Teeth in big gear, nos. | 80 |
| Teeth in small gear, nos. | 21 |
| Weight, kg | 38 |
| Operating speed, r.p.m. | 400 |

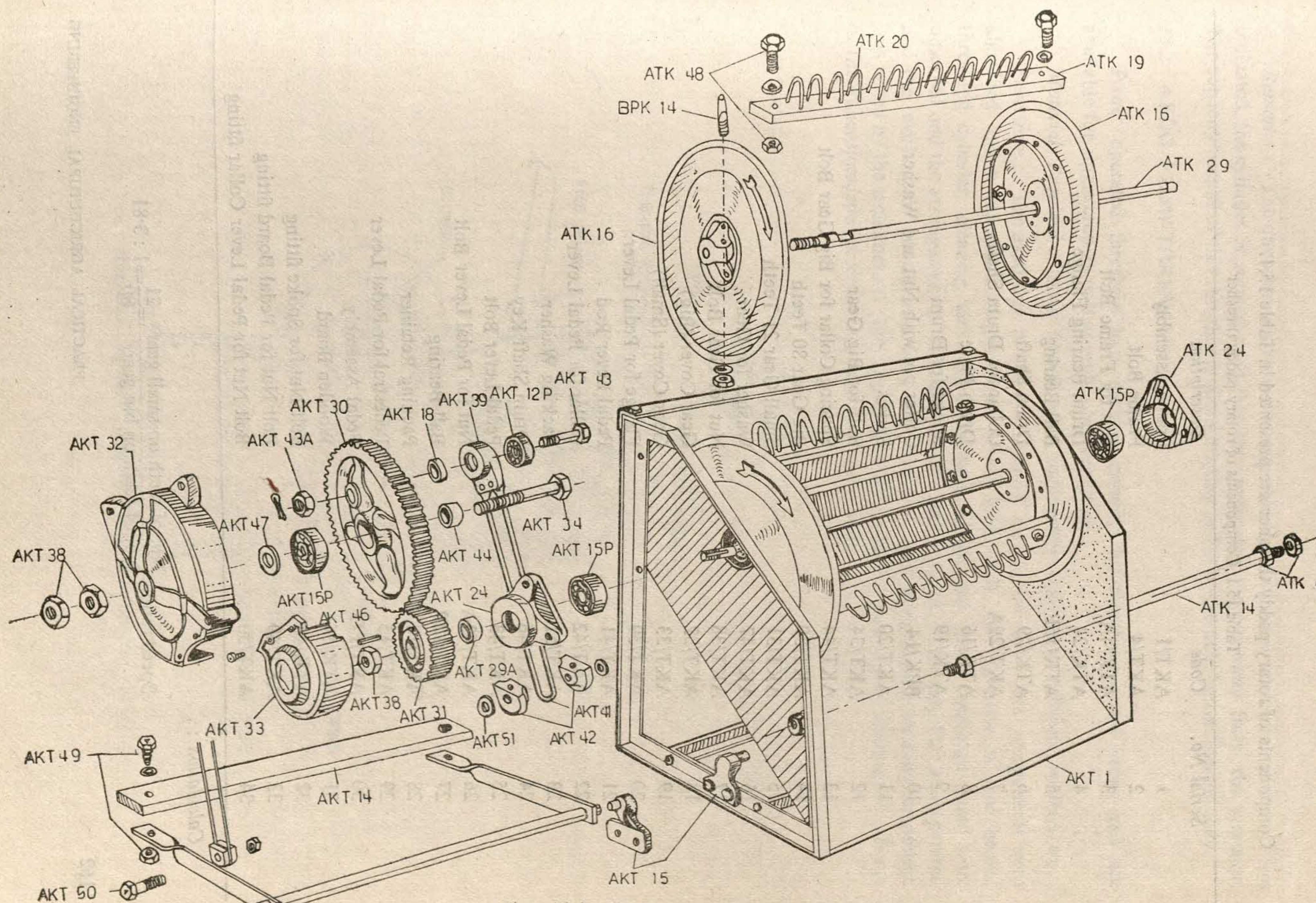


Fig. 15.1 Rotary paddy thresher (vide table 15.1)

Components of rotary paddy thresher are presented in Table 15.1.

Table 15.1 Components of rotary paddy thresher

| *Serial No.* | *Code* | *Description* |
|---|---|---|
| 1 | AKT/1 | Frame Assembly |
| 2 | AKT/4 | Frame Bolt |
| 3 | ATK/4A | Nut for Frame Bolt |
| 4 | ATK/24 | Drum Bearing Flange |
| 5 | ATK/15P | Ball Bearing |
| 6 | ATK/29 | Drum Shaft |
| 7 | AKT/29A | Collar for Drum Shaft |
| 8 | ATK/16 | Drum Plate |
| 9 | ATK/19 | Spoke for Drum |
| 10 | BPK/14 | Cotter pin with Nut and Washer |
| 11 | AKT/20 | Spikes |
| 12 | AKT/34 | Bolt for Big Gear |
| 13 | AKT/44 | Spacing Collar for Big Gear Bolt |
| 14 | AKT/30 | Big Gear 80 Teeth |
| 15 | AKT/31 | Small Gear 21 Teeth |
| 16 | AKT/47 | Washer for Gear |
| 17 | AKT/38 | Nut for Gear Bolt |
| 18 | AKT/32 | Gear Cover (Big) |
| 19 | AKT/33 | Gear Cover (Small) |
| 20 | AKT/39 | Flange for Pedal Lever |
| 21 | AKT/41 | Pedal Lever Rod |
| 22 | AKT/42 | Collar for Pedal Lever |
| 23 | AKT/51 | Packing Washer |
| 24 | AKT/46 | Drum Shaft Key |
| 25 | AKT/43 | Pedal Lever Bolt |
| 26 | AKT/43A | Nut for Pedal Lever Bolt |
| 27 | AKT/12P | Ball Bearing |
| 28 | AKT/18 | Packing Retainer |
| 29 | AKT/15 | Pedestral for Pedal Lever |
| 30 | AKT/PD | Pedal Assembly |
| 31 | ATK/14 | Wooden Board |
| 32 | ATK/48 | Bolt Nut for Spoke fitting |
| 33 | AKT/49 | Bolt Nut for Pedal Board fitting |
| 34 | AKT/50 | Bolt Nut for Pedal Lever Collar fitting |

*Calculation* :

$$\text{Speed ratio} = \frac{\text{No. of teeth on small gear}}{\text{No. of teeth on big gear}} = \frac{21}{80} = 1 : 3{\cdot}81$$

*Remarks* : The direction of rotation is generally indicated on the drum plate. If not indicated, the cylinder is rotated such that the grains are thrown away from the operator. The capacity/output of this thresher is about 2 q/day and it is operated by one person only.

## 15.2 AXIAL FLOW THRESHER

Power operated threshers have become popular for threshing cereal crops and are available for single crop as well as multi-crop threshing.

*Materials Required* : Axial flow thresher, tachometer, scale, tape, callipers, toolbox, etc.

*Procedure* : The axial flow thresher was placed on a level floor. Its components were identified and a schematic diagram was drawn (Fig. 15.2). The location of feed board, threshing cylinder, cleaning unit, grain discharge chute and straw discharge guard were observed and the arrangement of the different units was studied. The thresher was operated and the working of the different units was observed. The speed of each rotating component was noted by the tachometer. The frequency of the oscillating screen was determined. Some of the dimensions/specifications were measured and noted.

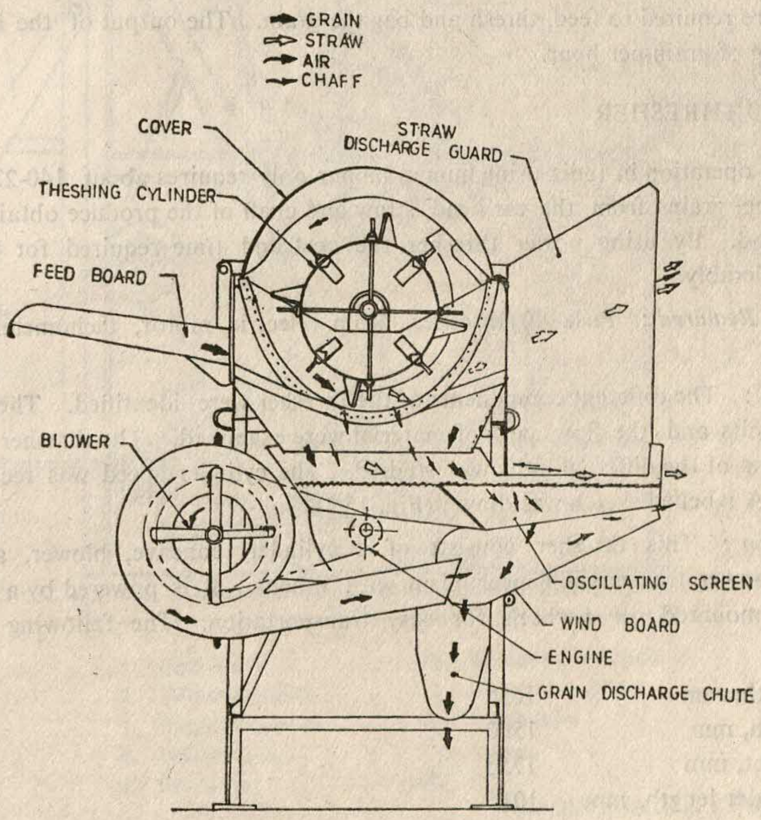


Fig. 15.2. Schematic diagram of axial flow thresher

*Observation* : The thresher consists of a feed board, threshing cylinder, oscillating screen for separating grain from straw, blower to clean the grain, grain discharge chute and straw discharge guard. The thresher is operated by a 7-h.p. engine. The following specifications are noted :

| | |
|---|---|
| Length, mm | 1190 |
| Width, mm | 1320 |
| Height, mm | 1500 |
| Cylinder type | Spike tooth |
| Cylinder diameter, mm | 305 |
| Cylinder length, mm | 710 |
| Cylinder speed, r.p.m. | 600 |
| Fan speed, r.p.m. | 800 |
| Oscillating screen frequency, cycles/min | 800 |
| Developed at | International Rice Research Institute, Philippines. |

*Remarks* : It is a portable machine and can be carried by four persons. Three to four persons are required to feed, thresh and bag the grain. The output of the axial thresher is about 450 kg of grain per hour.

## 15.3 PUSA 40 THRESHER

Threshing operation in India using human labour only requires about 140-220 man-hours to separate the grains from the ear head, straw and chaff of the produce obtained from one hectare of land. By using power thresher the cost and time required for threshing are reduced considerably.

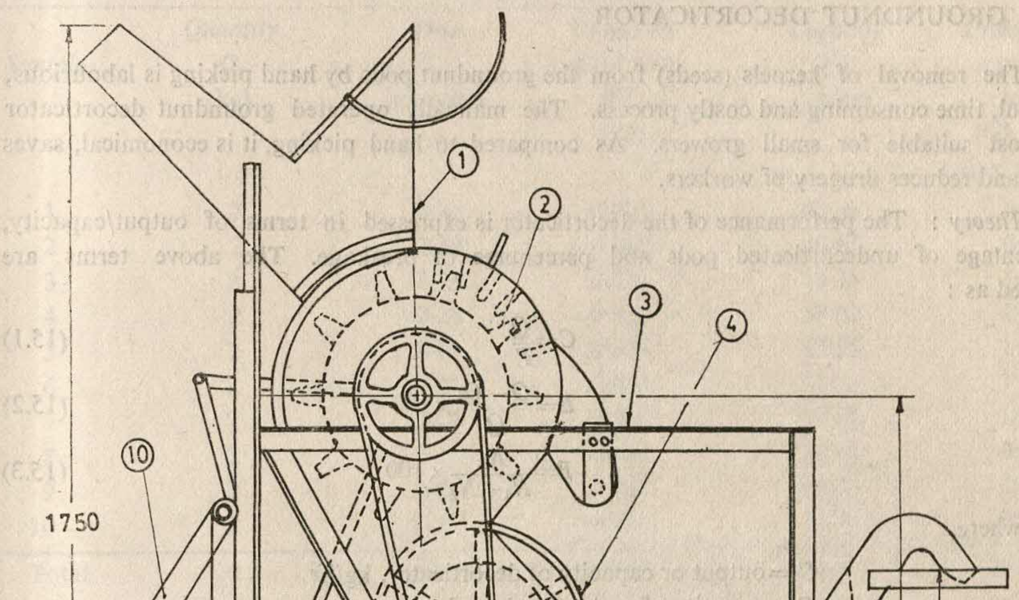
*Materials Required* : Pusa 40 thresher, 5-h.p. electric motor, tachometer, tape, scale, toolbox, etc.

*Procedure* : The different components of the thresher were identified. The arrangement of different units and the flow path of material were examined. The thresher was operated and the working of the different units was studied. The cylinder speed was recorded by the tachometer. A labelled sketch was drawn (Fig. 15.3).

*Observation* : This thresher consists of a cylinder, concave, blower, auger, sieves, elevator and power transmission mechanism with V-belts. It is powered by a 5-h.p. electric motor. It is mounted on 4 wheels for easy transportation. The following specifications are noted.

| | |
|---|---|
| Length, mm | 1650 |
| Width, mm | 1500 |
| Height, mm | 1750 |
| Cylinder length, mm | 1015 |
| Cylinder speed, r.p.m. | 600 |

| | |
|---|---|
| Type | Power operated |
| Prime mover | 5-h.p. electric motor |
| Developed at | Indian Agricultural Research Institute, New Delhi |



1. Feed hopper
2. Threshing drum
3. Angle iron frame
4. Beater drum
5. Blower fan
6. Elevator grain chute
7. Air blast regulator
8. V-belt drive
9. Shaker
10. Hitch

ALL DIMENSIONS IN MM

Fig. 15.3. Pusa 40 thresher

*Remarks* : This thresher is suitable for threshing wheat, barley, paddy, pearl millet, safflower and sorghum. The output is 2 quintals per hour for wheat threshing.

## 15.4 GROUNDNUT DECORTICATOR

The removal of kernels (seeds) from the groundnut pods by hand picking is labourious, painful, time consuming and costly process. The manually operated groundnut decorticator is most suitable for small growers. As compared to hand picking, it is economical, saves time and reduces drugery of workers.

*Theory* : The performance of the decorticator is expressed in terms of output/capacity, percentage of undecorticated pods and percentage of breakage. The above terms are defined as :

$$C=\frac{Q}{T} \tag{15.1}$$

$$E=\frac{Q-Q_1}{Q}\times 100 \tag{15.2}$$

$$B=\frac{N_2}{N_1+N_2}\times 100 \tag{15.3}$$

where,

$C$ =output or capacity of decorticator, kg/hr
$Q$ =quantity of pod decorticated, kg
$T$ =time taken for decorticating $Q$ kg of pod, hr
$E$ =decortication efficiency, per cent
$Q_1$=quantity of undecorticated pod, kg
$B$ =breakage of kernels (seed), per cent
$N_1$=unbroken kernels in each sample, kg
$N_2$=broken kernels in each sample, kg

*Materials Required* : Manually operated groundnut decorticator, weighing balance, 20 kg groundnut pods, scale, tape, paper bags, toolbox, etc.

*Procedure* : The components of the manually operated groundnut decorticator were identified. An isometric view of the groundnut decorticator was drawn and labelled (Fig. 15.4). The general specifications were observed and noted. Five samples, each of one kg weight, were made. Each sample was decorticated and time taken for decortication was noted. The undecorticated pods were separated and weighed. The unbroken and broken kernels were separated and weighed.

*Observation* : The general specifications are noted below

| | |
|---|---|
| Length, mm | 500 |
| Width, mm | 300 |
| Height, mm | 965 |
| Weight, kg | 14 |
| Manufacturer | Gujarat Agro Industries Corporation (GAIC), Ahmedabad. |

The experimental data and performance evaluation parameters are presented in Tables 15.2 and 15.3.

Table 15.2 Capacity and pod loss during decortication by GAIC groundnut decorticator

| *Sample* | *Quantity* $Q$ (kg) | *Time* $T$ (min-sec) | *Undecorticated pods* $Q_1$ (kg) | *Capacity* $Q/T$ (kg/hr) | *Undecorticated pod loss* $100\ Q_1/Q$ (per cent) |
|---|---|---|---|---|---|
| 1 | 2 | 2-30 | 0·022 | 48·00 | 1·10 |
| 2 | 2 | 2-25 | 0·018 | 49·65 | 0·90 |
| 3 | 2 | 2-23 | 0·024 | 50·35 | 1·20 |
| 4 | 2 | 2-20 | 0·022 | 59·02 | 1·10 |
| 5 | 2 | 2-17 | 0·026 | 52·55 | 1·30 |
| 6 | 2 | 2-21 | 0·020 | 51·06 | 1·00 |
| 7 | 2 | 2-17 | 0·020 | 52·55 | 1·00 |
| 8 | 2 | 2-18 | 0·018 | 52·17 | 0·09 |
| 9 | 2 | 2-23 | 0·020 | 50·35 | 1·00 |
| 10 | 2 | 2-22 | 0·022 | 50·70 | 1·10 |
| Total | 20 | 22-36 | 0·212 | 515·40 | 10·50 |
| Average | 2 | 2-216 | 0·021 | 51·64 | 1·05 |

Table 15.3 Loss due to breakage by GAIC groundnut decorticator

| *Sample* | *Quantity decorticated* $Q$ (kg) | *Whole kernel* $N_1$ (kg) | *Broken kernel* $N_2$ (kg) | *Breakage loss* $\frac{N_2}{N_1+N_2}\times 100$ (per cent) |
|---|---|---|---|---|
| 1 | 2 | 1·254 | 0·054 | 4·12 |
| 2 | 2 | 1·276 | 0·054 | 4·06 |
| 3 | 2 | 1·262 | 0·040 | 3·07 |
| 4 | 2 | 1·254 | 0·042 | 3·24 |
| 5 | 2 | 1·276 | 0·058 | 4·35 |
| 6 | 2 | 1·260 | 0·054 | 4·10 |
| 7 | 2 | 1·294 | 0·040 | 3·00 |
| 8 | 2 | 1·242 | 0·044 | 3·42 |
| 9 | 2 | 1·280 | 0·056 | 4·19 |
| 10 | 2 | 1·258 | 0·056 | 4·26 |
| Total | 20 | 12·656 | 0·498 | 37·81 |
| Average | 2 | 1·266 | 0·050 | 3·78 |

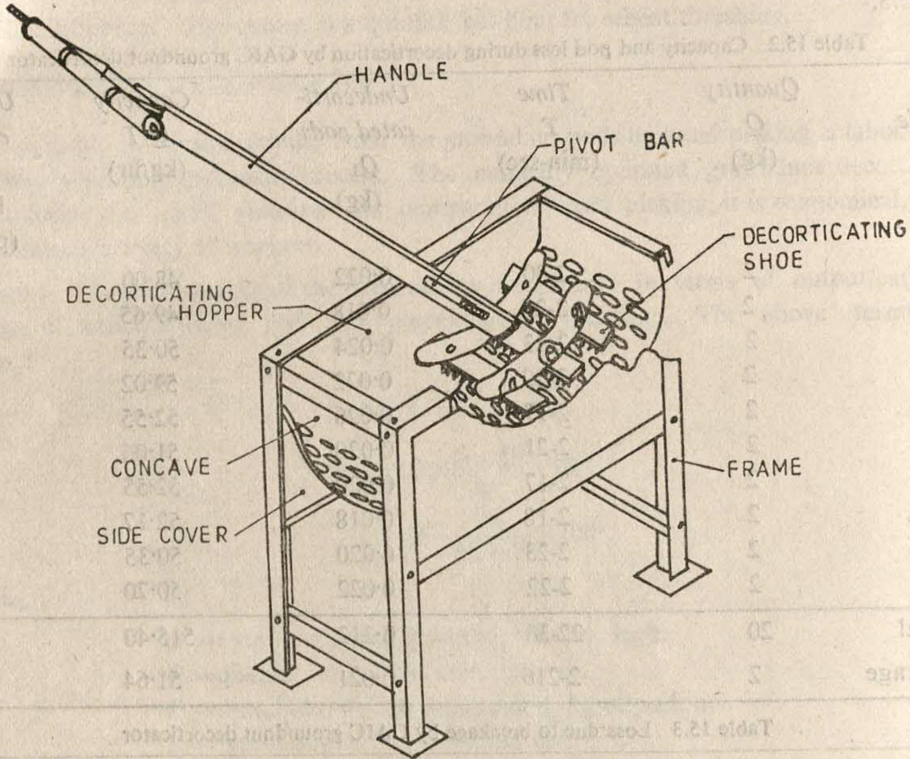


Fig. 15.4. Manually operated groundnut decorticator (oscillating type)

*Conclusion* : The capacity of the manually operated groundnut decorticator is found to be 51·64 kg/hr. About 1 per cent of the pods remain unshelled. The broken kernels account for 3·78 per cent.

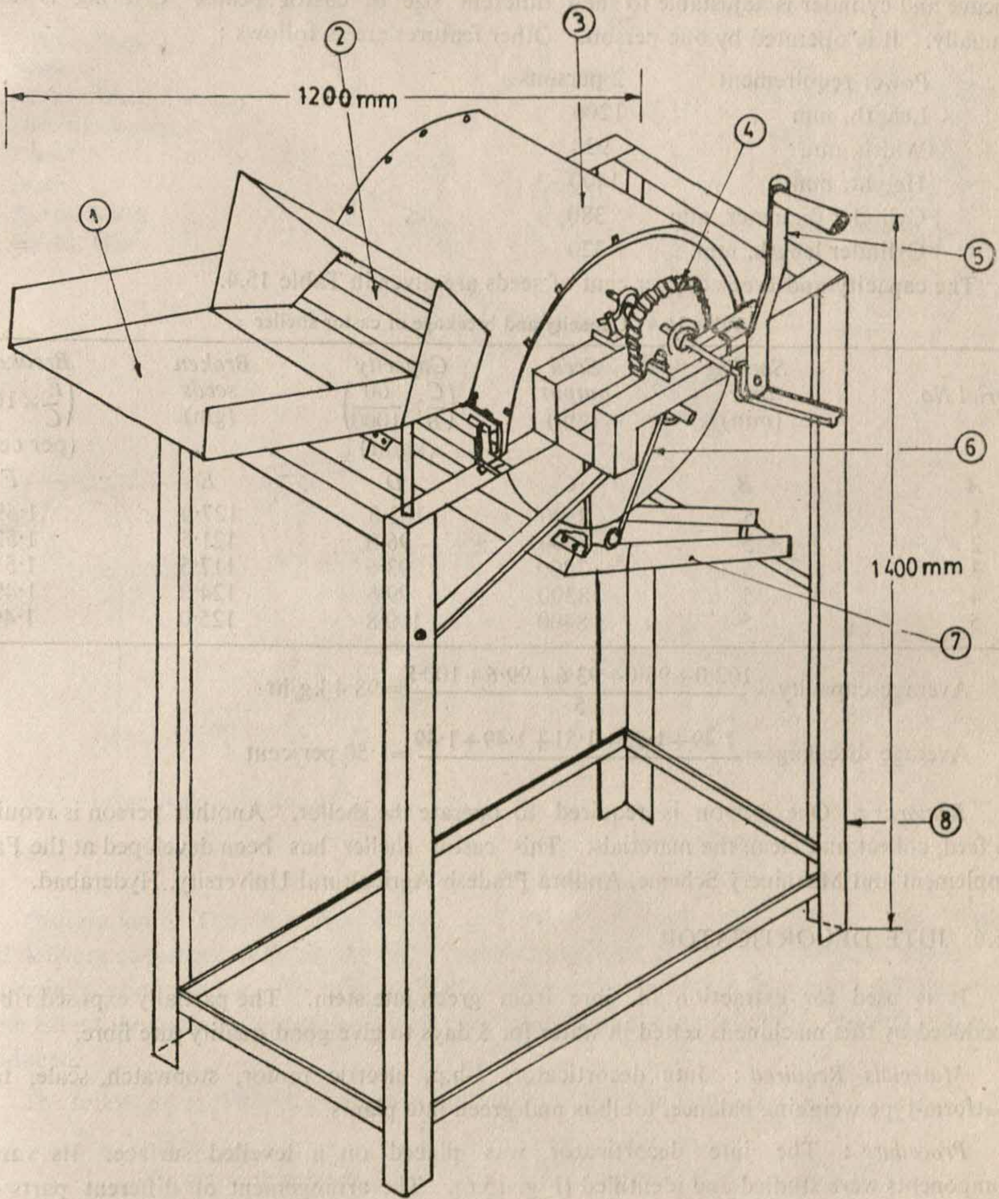
## 15.5 CASTOR SHELLER

This manually operated machine is used for shelling of castor pods.

*Materials Required* : Castor sheller, castor pods, weighing balance, scale, tape, toolbox, etc.

*Procedure* : The castor sheller was studied and a labelled sketch was drawn (Fig. 15.5). The relevant dimensions were measured. It was operated and castor pods were fed. The seed output against a noted time was collected and weighed. The broken seeds were isolated and weighed. Based on these, the capacity and breakage percentage were determined.

*Observation* : The sheller consists of a wooden ribbed cylinder, concave, cylinder cover, feeding chute, discharge chute, drive mechanism and crank. The clearance between the



1. Feeding chute, 2. Cylinder, 3. Cylinder curve, 4. Drive mechanism,
5. Crank, 6. Clearance adjustment, 7. Discharge chute, 8. Frame

Fig. 15.5. Castor sheller

concave and cylinder is adjustable to shell different size of castor beans. Clearing is done manually. It is operated by one person. Other features are as follows :

| | |
|---|---|
| Power requirement | 2 persons |
| Length, mm | 1200 |
| Width, mm | 920 |
| Height, mm | 1400 |
| Cylinder diameter, mm | 380 |
| Cylinder length, mm | 320 |

The capacity and breakage per cent of seeds are given in Table 15.4.

Table 15.4 Capacity and breakage of castor sheller

| *Serial No.* | *Shelling time* (min) | *Seed output* (gm) | *Capacity* $\left(\frac{C}{B}\times\frac{60}{1000}\right)$ (kg/hr) | *Broken seeds* (gm) | *Breakage* $\left(\frac{E}{C}\times 100\right)$ (per cent) |
|---|---|---|---|---|---|
| *A* | *B* | *C* | *D* | *E* | *F* |
| 1 | 5 | 8500 | 102·0 | 127·0 | 1·49 |
| 2 | 5 | 8000 | 96·0 | 121·5 | 1·52 |
| 3 | 5 | 7800 | 93·6 | 117·5 | 1·51 |
| 4 | 5 | 8300 | 99·6 | 124·0 | 1·49 |
| 5 | 5 | 8400 | 100·8 | 125·0 | 1·49 |

$$\text{Average capacity}=\frac{102{\cdot}0+96{\cdot}0+93{\cdot}6+99{\cdot}6+100{\cdot}8}{5}=98{\cdot}4 \text{ kg/hr}$$

$$\text{Average breakage}=\frac{1{\cdot}49+1{\cdot}52+1{\cdot}51+1{\cdot}49+1{\cdot}49}{5}=1{\cdot}50 \text{ per cent}$$

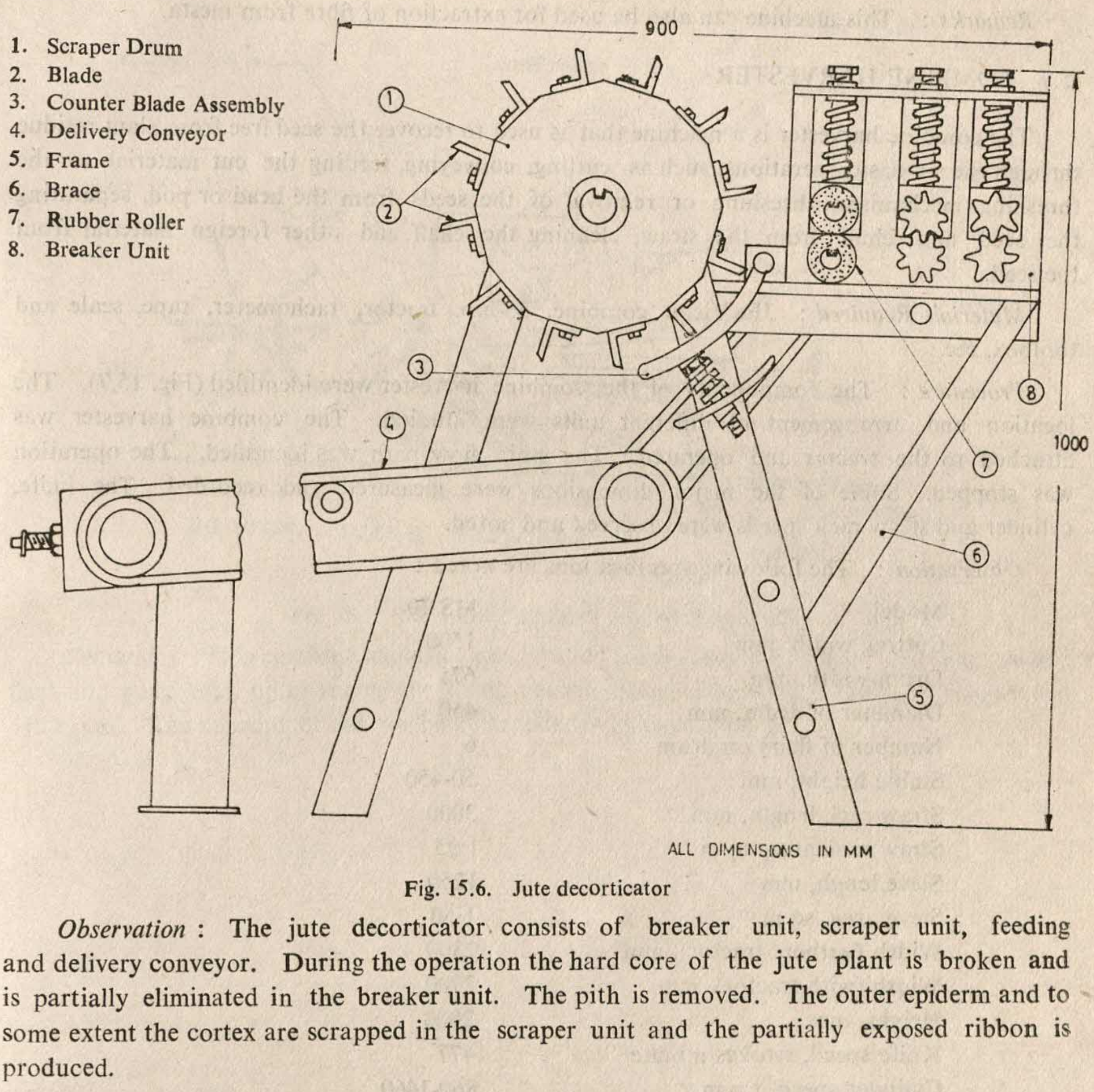
*Remarks* : One person is required to operate the sheller. Another person is required to feed, collect and clean the materials. This castor sheller has been developed at the Farm Implement and Machinery Scheme, Andhra Pradesh Agricultural University, Hyderabad.

## 15.6 JUTE DECORTICATOR

It is used for extraction of fibre from green jute stem. The partially exposed ribbon produced by this machine is retted in water for 5 days to give good quality jute fibre.

*Materials Required* : Jute decorticator, 5-h.p. electric motor, stopwatch, scale, tape, platform-type weighing balance, toolbox and green jute plants.

*Procedure* : The jute decorticator was placed on a levelled surface. Its various components were studied and identified (Fig. 15.6). The arrangement of different parts and that for power transmission was studied. The machine was connected to the 5-h.p. electric motor placed on a suitable platform witb good foundation. The machine was operated by starting the electric motor. Weighed quantity of green jute plant was fed into the machine. The time taken to decorticate the known quantity of green jute was recorded by a stopwatch to determine the capacity of the decorticator. The motor was disconnected and weight of the decorticator was taken.



1. Scraper Drum
2. Blade
3. Counter Blade Assembly
4. Delivery Conveyor
5. Frame
6. Brace
7. Rubber Roller
8. Breaker Unit

Fig. 15.6. Jute decorticator

*Observation* : The jute decorticator consists of breaker unit, scraper unit, feeding and delivery conveyor. During the operation the hard core of the jute plant is broken and is partially eliminated in the breaker unit. The pith is removed. The outer epiderm and to some extent the cortex are scrapped in the scraper unit and the partially exposed ribbon is produced.

The following specifications are noted for the jute decorticator :

| | |
|---|---|
| Type | Power operated |
| Power requirement | 5-h.p. electric motor and 2 persons |
| Length, mm | 900 |
| Width, mm | 620 |
| Height, mm | 1000 |
| Weight, kg | 156 |
| Capacity, q/hr | 4·6 (Green jute) |
| Developed at | Jute Agricultural Research Institute, Barrackpore, West Bengal. |

*Remarks* : This machine can also be used for extraction of fibre from mesta.

## 15.7 COMBINE HARVESTER

The combine harvester is a machine that is used to recover the seed free from plant residue through the six basic operations, such as cutting, conveying, feeding the cut material to the threshing mechanism, threshing or removal of the seeds from the head or pod, separating the seed and chaff from the straw, cleaning the chaff and other foreign material from the seed.

*Materials Required* : JF Vicon combine, 35-h.p. tractor, tachometer, tape, scale and toolbox, etc.

*Procedure* : The components of the combine harvester were identified (Fig. 15.7). The location and arrangement of different units were studied. The combine harvester was attached to the tractor and operated. The grain flow path was identified. The operation was stopped. Some of the major dimensions were measured and recorded. The knife, cylinder and straw rack speeds were observed and noted.

*Observation* : The following specifications are noted :

| | |
|---|---|
| Model | MS 70 |
| Cutting width, mm | 1500 |
| Drum width, mm | 675 |
| Diameter of drum, mm | 450 |
| Number of flairs on drum | 6 |
| Stuble height, mm | 50-450 |
| Straw rack length, mm | 3000 |
| Straw rack area, sq m | 1·95 |
| Sieve lengh, mm | 1250 |
| Sieve area, sq m | 1·50 |
| Width (without tractor), mm | 2300 |
| Width (with tractor), mm | 2900 |
| Height, mm | 2000 |
| Knife speed, strokes/minute | 477 |
| Cylinder speed, r.p.m. | 860-1460 |
| Straw rack speed, strokes/minute | 265 |
| Manufacturer | M/s Vicon Limited, 21 Ulsoor Road, Bangalore-42 |

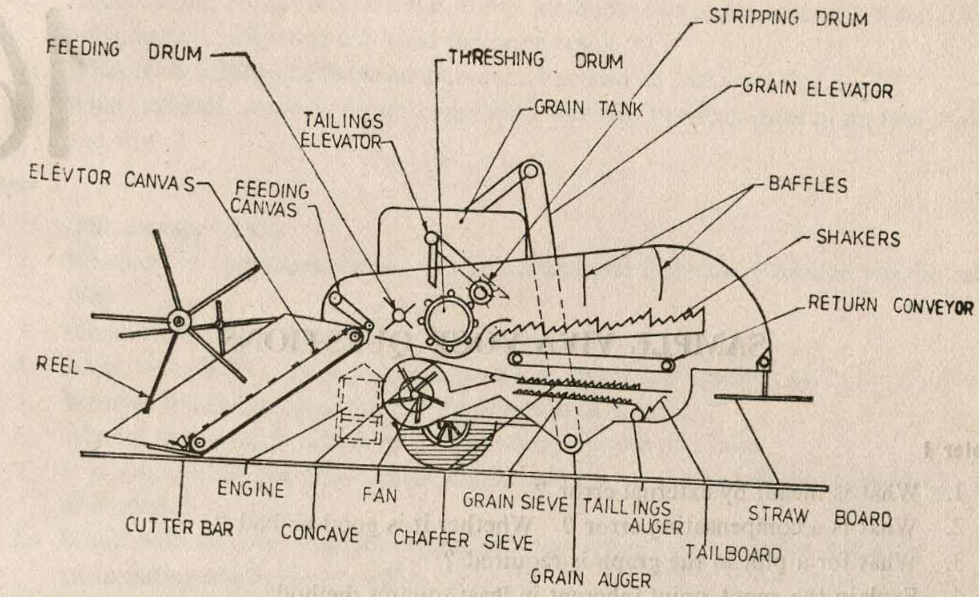


**Fig. 15.7. Schematic diagram of a combine harvester**

*Remarks* : This combine harvester can be used for barley, oats, wheat, rye, ragi, paddy, flax and peas, etc., by changing the drum speed. It is operated by 35-h.p. PTO power at 540 r.p.m. The capacity of the combine harvester is 15 to 20 q/hr.

# 16

# SAMPLE VIVA VOCE QUESTIONS

**Chapter 1**

1. What is meant by external error ?
2. What is a compensating error ? Whether it is good or bad ?
3. What for a plot in the graph is required ?
4. Explain the moot point inherent in least squares method.
5. Is it possible to express any type of plots in the graph through equation ?
6. Distinguish between empirical and mathematical equations.
7. To establish an equation, such as $y=a_0(x_1-x)^b$ from a set of experimental data how to choose the value of $x_1$ ?
8. What do you mean by trial and error method ?

**Chapter 2**

1. Is it possible to get rainfall intensity values from a non-recording type of rain gauge ?
2. How rainfall intensity can be ascertained directly ?
3. Why rainfall intensity is required to be ascertained ? Which one is more important—total rainfall or rainfall intensity ?
4. Why the total length of abscissa in a rain-gauge chart is 25 hours instead of 24 hours ?
5. What is the difference between the plot of cumulative rainfall versus time and the plot available directly from a rain-gauge chart ?
6. Under what conditions a rainfall is denoted as excessive ?
7. To characterise the climate of any region it is very often called that the said region is 'humid' or 'semi-arid', etc. How we can arrive at such conclusions ?
8. What is meant by frequency of a rainfall ?
9. To categorise an area as arid zone, how many year's data on weather are required in general ?
10. What is the significance of mean temperature of a place ?
11. What is the usefulness of arithmetic mean of rainfall over an wide area ?
12. What is the difference between weighted mean and the mean determined through Thiessen polygon method ?

13. Under what conditions all the three methods (viz., Arithmetic mean, Thiessen polygon and Isohyetal) will yield the same result ?
14. What is the difference between a contour line and an isohyetal line ?
15. What rainfall value is to be considered for the two end areas in an isohyetal map and why ?

**Chapter 3**

1. Define evaporation.
2. Whether the evaporation from a lake surface and from a soil surface will be same ? Why ?
3. What does the pan-evaporation data indicate ?
4. What is the difference between evaporation and evapotranspiration ?
5. Whether urbanisation affects the evaporation of a place ?
6. What is the physical significance of consumptive use of a crop ?
7. Is it worthwhile to concentrate human efforts on the reduction of consumptive use of a crop ?
8. What will be the evapotranspiration rate when the relative humidity in the surrounding atmosphere is 100% ?
9. Differentiate between the water requirement of a crop and the consumptive use.
10. What is crop coefficient ?
11. What are the limitations of Thorthwaite method ?
12. What is the difference between evapotranspiration and consumptive use of a crop ?

**Chapter 4**

1. What for moisture content of a soil is determined ?
2. Which one is the best method to determine moisture content of a soil ?
3. Why in gravimetric method a soil sample is kept in an electric oven for 24 hours (and not less than this) at 105 °C (and not at higher or lower temperature) ?
4. What is the basic difference in principle and operation of a tensiometer and a gypsum block ?
5. What are the limitations in tensiometers and gypsum blocks ?
6. What is meant by the term calibration ?
7. Why all other methods are calibrated with the data on gravimetric method ?
8. What are the possible ways of expressions of calibration ?
9. How a tensiometer is installed in the crop field ?
10. What will happen if the calibration is made on the data of wetting cycle ?
11. Name the metals which can be used as electrode for gypsum blocks.
12. What type of electrode (viz., wire mess, flat metal, etc.) is more effective ?
13. What happens if the slurry of water and plaster of Paris in the ratio of 2 : 1 is used for casting ?
14. What happens if the air bubble remains encapsulated in a gypsum block ?
15. What is meant by curing of a gypsum block ?
16. What is wrong if a gypsum block is calibrated against a tensiometer ?

17. What would be the resistance in ohms if the soil in which a gypsum block has been installed dries up to the zero percentage of moisture content ?
18. Whether the resistance offered by a gypsum block will be same when (i) dipped in pure water and (ii) installed in a soil of 100% moisture content ? Explain the reasons.
19. What is meant by standardisation ? What for it is needed ?
20. How far the data obtained using a gypsum block are reliable ?
21. Whether the soil parameters like specific heat capacity, thermal conductivity, thermal diffusivity, etc., are affected by bulk density ?
22. If the wet bulk density of a soil is $P_t$ whether dry bulk density of the same soil will be higher (or lower) than $P_t$ ?
23. What is the difference between wet bulk density and dry bulk density ?
24. There are two soils. One is light and another is heavy. Both are just saturated. Which one will have higher wet bulk density ?
25. There are two soils. One is very loose and another is very tight. The moisture content in both the soils is same. Which one will have lower wet bulk density ?
26. Why dry bulk density is less than particle density ?
27. Whether there is a tendency for the dry bulk density to rise with profile depth ?
28. What is the relation between compactness and dry bulk density of any soil ?
29. There are two soils. One is well-granulated silt loam surface soil and another is sandy loam. Which one will have lower dry bulk density ?
30. 'Bulk density (dry) is a second and different method of expressing soil weight.' Explain.
31. Define porosity of a soil.
32. In what way the method of expressing moisture content (%) of soil is inferior to the method of volumetric moisture content ($\theta$) ?
33. Differentiate between saturation and porosity.
34. There are sandy soils, medium-textured soils and clayey soils. What are the approximate ranges of $\theta$-values at saturation for these soils ?
35. Knowing porosity how void ratio can be determined ?
36. Name all the methods to determine infiltration characteristics of a soil.
37. Why the knowledge of infiltration characteristics is essential ?
38. What are the assumptions based on which Lewis-Kostiakov's infiltration equations have been developed ?
39. Whether the infiltration characteristics of a real-world soil (*in situ*) is same irrespective of the time scale ?
40. What are the differences between permeability and infiltration of a soil ?
41. Name all the methods to determine permeability of any soil ? Which one is best and why ?
42. In absence of a sophisticated equipment, how will you proceed to determine permeability in an idiginous way ?
43. What are the basic differences between constant head and variable head methods ?

44. List all the factors on which permeability of a soil depends.
45. Which of the permeabilities is best suited for irrigation practices ?
46. What will happen with the rate of infiltration if time (from the onset of an infiltration event) tends to infinity ?
47. How far the method of determination of permeability of surface soils *in situ* by prolonged infiltration test is useful for irrigation purposes ?
48. What will happen with the permeability if the bulk density increases ?
49. There are two soils. In one permeability is low and in another it is high. In which case the deep percolation loss will be more ?
50. Why the knowledge of aquifer permeability is useful ?
51. While boring a tubewell a soil sample from the aquifer is collected and placed in a constant head apparatus. The permeability is then determined. Can we use this as permeability of the aquifer soil for all practical purposes ? Make reasons why.
52. An engine of 5-h.p. is used to determine the permeability($K$) of an aquifer. It is noted that $K=K_1$. The above is then replaced by a 10-h.p. engine and the test is performed once again to note that $K=K_2$. Whether $K_1>K_2$ or $K_1<K_2$ or $K_1=K_2$ ?
53. Two tubewells having diameters of $d_1$ and $d_2$ ($d_1<d_2$) are used to determine $K$ of a same aquifer. Which one will show higher $K$ ?
54. To determine the permeability of an artisan aquifer a flowing artisan well is available. How the draw down curve can be prepared to calculate permeability ?
55. To record water levels in the piezometers, what is to be done in absence of an electric sounder ?

**Chapter 5**

1. In which direction the crest edge of an weir is placed ?
2. What are the standard conditions for weirs ?
3. At what point the depth (or height) of flow over the weir is to be measured ?
4. What are the disadvantages of weirs ?
5. What is meant by end contraction in rectangular weirs ?
6. How the coefficient of discharge of an weir can be estimated ?
7. In a channel having a mild bottom slope can we use a weir ? Why ?
8. What is the percentage error if $h$ is noted as $h_1$ ? In case ($h-h_1$) is small whether the error in determining $Q$ is large or small ?
9. What are the usefulness of a stilling well with baffled walls prior to the point of weir crest ?
10. Can we avoid stilling wells considering velocity of approach ?
11. What are the devices by which head or depth of water on a weir crest may be measured ?
12. Name the materials by which weirs can be made.
13. What is a portable weir ? Name the materials from which these are made. Explain how those are used.

14. How an weir can be calibrated ?
15. What will be the nature of curve if depth versus discharge data are plotted on a log-log paper ?
16. 'A current meter is a miniature reaction turbine.' Explain.
17. How a current meter is calibrated ?
18. How many types of current metres are there ?
19. Explain the mechanism by which number of revolutions is counted.
20. What are the precautions to be taken for working with a current meter ? What is the accuracy of the results ?
21. What will happen if heavy floats are used ? Name some possible floats.
22. Why the velocity of a float is multiplied by a constant (lying in between 0·8 to 0·9) ?
23. What is meant by the term mean velocity of water flow ? Where does this exist ?
24. Whether the float method is good for a deep flow or a shallow flow ? Make reasons why.
25. Comparing float method with that of salt velocity method which one seems to be better ?
26. Explain how the value of (channel slope) can be obtained to be used in Manning's formula.
27. In general why the slope of the channel bottom is used in Manning's formula ? Explain the possibilities of errors.
28. How the value of roughness coefficient is to be chosen ? Is it dimensionless ?
29. Whether Manning's formula is dimensionally homogeneous ? What are the factors on which Manning's $n$ depend ?
30. Can we apply Manning's flow formula in pipe flow ?
31. What is the relation between Chezy's $C$ and Manning's $n$ ?
32. What is the physical significance of hydraulic radius ? What is the difference between hydraulic radius and radius of a pipe flowing just full ?
33. Whether Chezy's formula can be derived mathematically ? If so what are the assumptions ?
34. Chezy's formula has a theoretical background, while Manning's is a pure empirical. Why then Manning's formula is widely used in agricultural flow problems instead of Chezy's ?
35. What factors are responsible for the variation in the values of Chezy's $C$ ?
36. List all the methods by which discharge of a tubewell can be measured.
37. On what factors the discharge of a tubewell depends ?
38. What is the basic difference in estimating maximum yeild of a tubewell drilled in an unconfined aquifer and in a confined aquifer ?
39. A 5-h.p. diesel and an electric engine are used to pump water from a same tubewell. In which case the discharge will be more ?
40. Will the discharge of clear water and muddy water be same, if all other conditions of the two tubewells are identical ?

## Chapter 6

1. Why it is needed to know the drainage coefficient of a land ?
2. Whether the data of a laboratory model study on drainage coefficient will be of any help to the real field ?
3. Are there any mathematical-physical rules to set up a laboratory model to represent the real world situations ? What are those ?
4. What are the similarities and differences in the runoff coefficient (Rational formula $Q$=CIA) and the drainage coefficient ?
5. On what factors the drainage coefficient of a land depend ?

## Chapter 7

1. Discuss on the utilities of a topographic survey.
2. Why scale in a topographic map is very important ?
3. What are meant by topography and topographic survey ?
4. List the equipments needed for a topographic survey.
5. What are the differences in topographic maps and air photographs or photographs obtained through satellites ?
6. Why two contour lines cannot intersect at a point ?
7. There are two contour maps of a place. One contains lines concentrated only on the south-eastern zone and another contains contour lines uniformly scattered throughout the whole area. Which one of the two is best ? Why ?
8. What is the moot point of consideration to avoid concentration of a few contour lines in a particular zone out of the whole area ?
9. Is it necessary to have same contour interval throughout the map of a place ?
10. What points are to be considered to study a contour map ?
11. What do you propose to calculate the volume of a pond which is geometrically regular in shape ?
12. The banks of a pond in one side is higher than the other. What is the difference in the volume of earthwork and the volume of water storing capacity of the pond ?
13. Following contour method closed contours will not be available beyond the highest possible water level for the above case. How then the total volume of earthwork can be calculated ?
14. Sometimes staff in its fullest height is not visible through Dumpy Level placed on the ground surface, when it is being placed in or around the bottom of the pond. How then the reading of the RLs can be ascertained ?
15. What will you do to survey the pond for calculation of its volume in case you find that there is waist-depth water in the pond ?
16. Why witnesses are wilfully kept in any earthwork from the surface soils ?
17. What is the manner of payment as labour cost for earthwork ?
18. What procedure is to be followed to estimate the earthwork if the soil has already been placed properly for road making ?

19. How the earthwork of an irregular-shaped (not straight) earthen channel can be estimated ?
20. How do you propose to estimate the earthwork involved in the construction of an earthen dam which has been built some years back ?

**Chapter 8**

1. What is meant by indigenous plough ?
2. Name the various parts of an indigenous plough.
3. Which factor does influence the size of the plough and beam ?
4. Name the different parts of a grain harvesting tool (sickle).
5. Name some of the improved sickles and their respective manufacturers.
6. Give the difference in manufacturing process followed in shaping the cutting edge of the local and improved sickle.
7. What are the uses of hand tools ?
8. Name some of the common hand tools used by our farmers.

**Chapter 9**

1. What is primary tillage ?
2. Name the various parts of a mouldboard plough.
3. What are the four distinct operations achieved by a mouldboard plough ?
4. What is vertical/horizontal clearance ?
5. What are the commonly used specifications to describe a mouldboard plough ?
6. Name the major parts of a tractor-operated mouldboard plough.
7. State the correct order of attachment to be followed during hitching of a tractor-mounted plough.
8. What is the main objective in field adjustment of a tractor-mounted mouldboard plough ?
9. What are the conditions for using disc plough for field operation ?
10. What are the importance of disc and tilt angles in a disc plough ?
11. What are the recommended disc and tilt angles for nominal width of cut in different ploughing conditions ?
12. Name the important operations performed during the field adjustment of disc plough.

**Chapter 10**

1. What is secondary tillage ?
2. Name the implements used for secondary tillage operation.
3. How are the discs of the offset disc harrow (mounted) ?
4. Give the advantage of an offset disc harrow.
5. What are the different types of harrows ?
6. What are the uses of a cultivator ?
7. What are the different types of cultivators ?
8. Give the draw bar h.p. requirement of a 9-tyne cultivator.

### Chapter 11

1. How do you adjust the row setting of a single row seed drill ?
2. Name the different types of furrow openers used in seed drills and specify the field condition for each type.
3. What is the field capacity of cup-feed-type bullock-drawn seed drill ?
4. What is calibration of a seed drill ?
5. Name the different parts of Jyoti planter.
6. What are the possible wheel settings for tractor during seed drill operation ?
7. What is the field capacity of a semi-automatic potato planter ?
8. What is the advantage of using plunger-augur fertilizer injector ?
9. How does the rate of fertilizer application be regulated in fertilizer injector ?

### Chapter 12

1. What are the advantages of using wheel hoe ?
2. When do you recommend the use of the three-tyned hand cultivator ?
3. What are the special features of a push-type hand weeder ?

### Chapter 13

1. Why the container of the hand compression sprayer is filled with liquid up to 3/4ths of its capacity ?
2. What is meant by the capacity of a hand compression sprayer ?
3. Why is it essential to calibrate the sprayer before application of the spray fluid ?
4. What are the advantages of using power sprayer ?
5. How can the spraying operation be converted to dusting operation in a mist blower ?

### Chapter 14

1. Describe the working principle of an animal-drawn engine-operated reaper ?
2. What is the necessity of using an engine in the animal-drawn engine-operated reaper ?
3. What are the advantages of a power-tiller-operated reaper ?
4. What is the field capacity of a power-tiller-operated reaper ?
5. Why the tractor-operated reaper is preferred over the power-tiller-operated reaper ?
6. Explain the arrangement of different units in a potato digger-cum-elevator ?
7. What is the utility of providing an elevator unit in potato digger ?

### Chapter 15

1. What is the source of power for operating a rotary paddy thresher ?
2. How the reciprocating motion of the wooden board is converted into the rotary motion of the cylinder in case of a rotary paddy thresher ?
3. What is the mechanical advantage in rotary paddy thresher ?
4. What is the optimum cylinder speed of rotary paddy thresher for threshing paddy ?
5. How does the axial flow thresher differ from other threshers ?
6. What is the source of power for operating the axial flow thresher ?

7. What is the basic difference between axial flow and Pusa 40 thresher ?
8. What arrangement has been provided in Pusa 40 thresher for easy transportation ?
9. What are the allowable range of pod loss and breakage of kernels during decortication ?
10. What is the capacity of a castor sheller ?
11. What are the basic operations performed by a combine harvester ?
12. What is the optimum cylinder speed of a combine harvester when used in paddy crop ?

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